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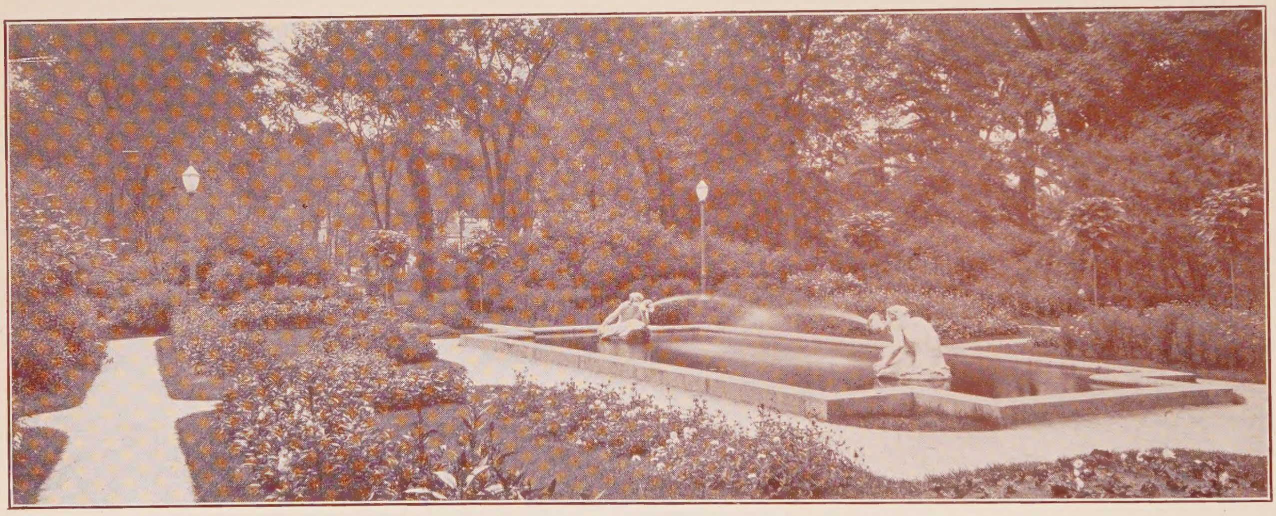
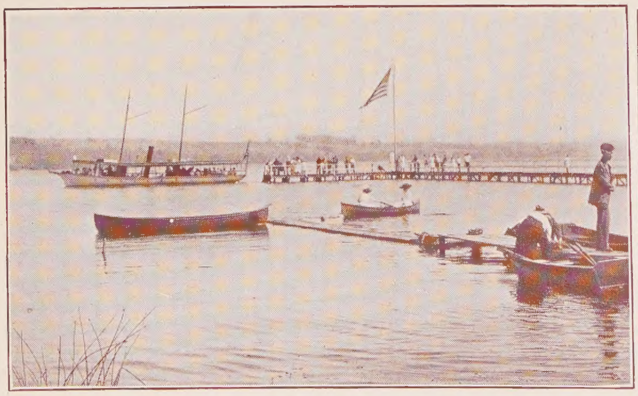
Annual Convention of the A. I. E. E.

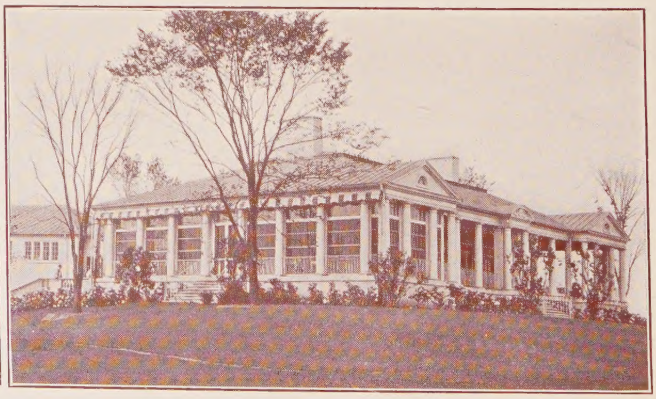
June 22-26, 1925



Fountain in Congress Springs Park, Saratoga Springs



View on Saratoga Lake



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Journal of the A. I. E. E.

Devoted to the advancement of the theory and practise of electrical engineering and the allied arts and sciences

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Our Railroad Meeting

After the routine business on the evening of the Annual Meeting, May 15, was held a session on Railroad Electrification, which was unique as well as beneficial in many ways. The outstanding feature of the meeting was the fact that the speakers were all executives and spoke from the executive rather than the technical standpoint. The purpose of the meeting was to make it known that the manufacturers of electrical systems applicable to steam railroads would now furnish any system decided upon as a desirable standard by the engineers representing the purchaser.

It is well known that for many years the divergence of engineering opinion among manufacturers has prevented a free, forward movement in railroad electrification, and it is with much satisfaction that through this meeting it was recorded that the way is clear for research and activity without limit in the matter of the electrification of our nation's railroads. The words of wisdom given by the speakers, and which will be found in this issue of the JOURNAL, indicate definitely the need for positive action in this field, and now, dating from May 15, 1925, starts a new era in railroad electrification possibilities; and that the members of our Institute are to have much to do with it is certainly gratifying. We must realize that our responsibility for the carrying on of this activity promptly and correctly is as great as its importance to national transportation.

FARLEY OSGOOD

Regional Meetings

Last year was initiated the holding of a Regional Meeting, the first one being near the end of the Institute year, on June 4 and 5, 1924 at Worcester, Mass. The excellence of the program soon became known to our membership and a realization, from the satisfactory carrying out of the District No. 1 Regional Meeting, that through such meetings could best be provided the outlet for the technical information of our Institute which could no longer be brought out in the small number of national meetings owing to the growth in our membership and Institute activities generally.

This year we have had two Regional Meetings, one of District No. 2 at Washington, D. C. on January 23-24, 1925, and recently, of District No. 1 a tSwampscott, Mass., May 7-9; and the programs and success of these meetings further demonstrate that the Institute is on the right track, and that through Regional Meetings not only will it be possible to bring forth more actual information for the benefit of the members, but there will be stimulated an interest in the Institute itself to a greater realization that its work is proceeding always for the benefit of the nation as a whole.

FARLEY OSGOOD

Some Leaders of the A. I. E. E.

Charles F. Scott, the fifteenth President of the Institute, was born at Athens, Ohio, September 19, 1864. He attended Ohio University in Athens and entered the Junior year at Ohio State University, Columbus, graduating A. B. in 1885. He took post-graduate work at Johns Hopkins University.

He began electrical work as wireman at the Baldwin Locomotive Works. In 1888 he was night assistant in the testing room of the Westinghouse Electric and Manufacturing Company. Later he was associated with Nikola Tesla in the development of his alternating-current motor. Subsequently he was made assistant electrician; in 1897, chief electrician and in 1904, consulting engineer. He proposed and took an active part in developing the Westinghouse Club, The *Electric Journal* and the Summer Conference for Engineering Teachers.

In 1911, he accepted the professorship of electrical engineering at the Sheffield Scientific School, Yale University, where he still continues.

Professor Scott was President of the Institute 1902-03. Upon his recommendation an active campaign for members was undertaken; the high-tension transmission committee was founded; section growth was stimulated (there was one active and one inactive section); and student branches were established. He advocated that the plans for a building for the Institute be extended to include other engineering societies and his advocacy of this idea at the annual dinner interested Mr. Carnegie, who was the honor guest. His gift of $1,500,000 followed and Professor Scott was chairman of the building committee representing the Engineering Societies and the Engineers' Club. He was charter member of United Engineering Society. He was a member of the Institute Development Committee in 1919 and a representative of the Conference Committee of the four founder societies which formulated plans for Federated American Engineering Society, now American Engineering Council, on which he has held continuous appointment as an Institute representative.

In 1902 he was president of the Engineers' Society of Western Pennsylvania. At the International Electrical Congress at St. Louis in 1904 he was chairman of the Power Transmission Section. During 1921-23 he was president of the Society for the Promotion of Engineering Education. He proposed undertaking an active study of Engineering Education; plans were developed, a grant of $108,000 was secured from the Carnegie Foundation, a Board of Investigation and Coordination was formed, of which he was made Chairman, and a director and staff were appointed. This work is now well underway; there are active committees in a hundred colleges and in various engineering societies, and there are other cooperating agencies.

Annual Technical Committee Reports

The work of the A. I. E. E. Technical Committees has been growing for the past several years until it has now become an important function in the activities of the Institute. When these committees were first organized their chief and almost sole function was to pass judgment on such contributed papers as fell within their respective fields. This work as a rule was done by the chairmen of the committees and there was, at first very little real committee activity. Later, the chairmen were made members of the Meetings and Papers Committee and in this way they obtained a broader insight into the work of the Institute which lead to the cooperation of all the committees in producing well balanced and timely programs for the various Institute meetings and conventions.

From reviewing papers, the work of the Technical Committees gradually expanded to cover the production of papers within their own membership, the suggestion of subjects for standardization, research work along certain lines, cooperation with other committees of the Institute and other organizations, news items for the JOURNAL, and the presentation of annual reports to the Board of Directors.

At the present time, several of the most important activities of the Institute hinge upon the action of the Technical Committees. Their work is such, however, that it does not bring them into very intimate contact with the bulk of the Institute membership and for this reason it is probably not as generally appreciated as it deserves to be. Their most important point of contact with the membership is through the Annual Committee Reports and these have been improving in character for several years past to an extent which has lead them to be featured prominently at the coming Annual Convention. These reports necessarily differ in form and scope, owing to the different branches of electrical engineering which they cover, but aside from the review of actual work accomplished by the Committee, these reports, by direction of the Board of Directors, contain a resumé of the current progress in the field of each Committee, which constitutes annually a brief history of the art. As the membership of these Technical Committees is composed of experts in their respective fields, there is no better channel than these reports for keeping fully abreast of developments in practically all branches of electrical engineering. Two sessions of the Annual Convention are to be devoted to the presentation and consideration of these reports this year. It is believed that these will not only prove very instructive but the reports will form permanent records of progress of great value to the Institute.

Engineers and Legislators

The Engineers of St. Louis have set a precedent which is worth chronicling. On Dec. 29 of last year, the engineers invited to a dinner, the members-elect of the coming legislature, with the promise that none of the legislators would be asked to speak, nor would any request or propaganda for support of any bills be introduced. The meeting was a great success; and thereafter, if any of the engineers had occasion to go to the legislature, they met friends instead of strangers. A still more interesting result was that when the measure proposing to license engineers came up, a few letters from engineers in St. Louis to members of the legislature with whom they had become acquainted at this dinner resulted in a recommendation from the committee to which the bill was referred, that it should not pass. A second measure to license engineers received even less attention.

The second experiment along this line was a dinner given on April 18 by the engineers to the Board of Aldermen, with whom the engineers had already established friendly working relations. There were twenty-three alderman guests and thirty-five engineer hosts. The menu card bore on the front the recommendation to the engineers: "Get Acquainted With Your Alderman. You May Like Him." And on the back, the suggestion to the aldermen: "Get Acquainted With the Engineer. You May Need Him." Philip N. Moore, mining engineer and geologist, acted as toastmaster. The speeches were all by engineers, and naturally had to do with the engineering problems of St. Louis.

A simple and natural method for engineers to get in touch with the men whose duty it is to legislate on engineering and industrial problems is here exemplified. Too often the engineers meet by themselves and discuss questions of policy and legislation which would be of great interest to the legislator, who never hears of them. —*Engineering and Mining Journal-Press.*

"The problem confronting engineers today is one of finding ever increasing means and spheres of service to profession, State and Nation, and of proving the Institute's right to be considered one of the permanent national bodies."—CALVERT TOWNLEY, President, 1919-20.

Power Possibilities at Muscle Shoals, Alabama

BY SAMUEL S. WYER[1]

Synopsis.—*This study was made in February and March, 1925. The author had access to the public records of the War Department but his responsibility for all statements is complete.*

Factual conveyance has been more important than euphony or euphemism. The object of the report is to present the basic facts pertaining to the whole Muscle Shoals situation in a way that the layman can make his own evaluation of,

1. What Muscle Shoals is

2. What has, and can be done at Muscle Shoals

and from these facts deduce as to what, in the public interest, on the basis of the greatest good to the greatest number, ought to be done with it.

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I. Fundamental Features

1. Public's Understanding of Term "Muscle Shoals." In the public's mind, the term "Muscle Shoals" is a definite spot and not the stretch of river described in Section 3. As used by the layman, Muscle Shoals means the water-power development now nearing completion at the Wilson Dam—named for President Wilson—and the term is so used in this study.

While the Wilson Dam is merely a small part of the proposed Tennessee River development, it is the only part now under construction and this is why the public's attention has been focused on it, rather than on the project as a whole.

2. Public's Interest in Muscle Shoals. At present Muscle Shoals is the most talked of power project in the world. No other water power has ever received so much oratorical attention, or has had expended on it so much printers' ink. The very name "Muscle Shoals" has become a symbol for power.

In the forum, in the press and in the conversation of the public, Muscle Shoals has frequently been the dominating topic of the day. From its inception as a war measure, public interest in it has grown until at times the preponderant public opinion has been that the military and economic strength of the nation was dependent upon Muscle Shoals.

3. Location of Muscle Shoals. The general geographical location of Muscle Shoals in northwestern Alabama is shown by Fig. 1, with local details in Fig. 2.

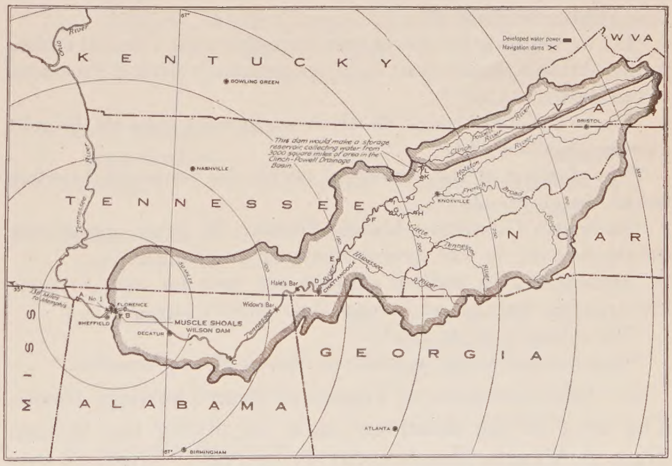

FIG. 1—MAP OF MUSCLE SHOALS DRAINAGE BASIN OF TENNESSEE RIVER

Possible future dam sites for navigation and power

Riverton........	A	Sale Creek.......	E	Senator.........	I
Number 3.......	B	White Creek.....	F	Melton Hill......	J
Guntersville.....	C	Marble Bluff.....	G	Clinton..........	K
Sherman........	D	Coulter Shoals...	H	Cove Creek......	L

1. Consulting Engineer, Columbus, Ohio.
To be presented at the Annual Convention of the A. I. E. E., Saratoga Springs, June 22-26, 1925.

For a distance of about 37 miles, between the railroad bridge at Florence and Brown's Island near Decatur, Alabama, the bed of the Tennessee River is really a series of shoals, one right after the other, with a fall of 140 feet in that distance.

The shoals near Florence are known as "Muscle Shoals," the muscle shell fish—earlier and now alternate spelling "Mussel"—were found in abundance in the bed of the shoals. The present geographical name "Muscle" has been derived from this fact. The Muscle Shoals section includes the stretch of river from Muscle Shoals up to Brown's Island.

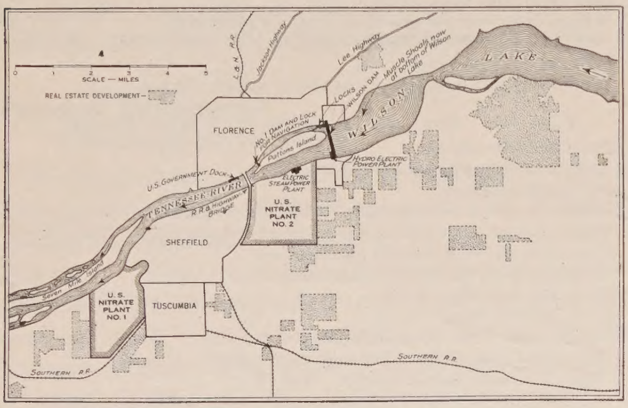

Fig. 2—Muscle Shoals District, Alabama, March 1925

4. Current Terms Applied to Muscle Shoals. The following are commonplace expressions for and representing current ideas of Muscle Shoals:

"There is no place in the world where greater advantages are to be found for the harnessing of water power for the uses of industry, or where there is greater power awaiting development, within reach of the seaboard by water and rail transportation, than at Muscle Shoals."[1]

"If I were greedy for power over my fellow men, I should rather control Muscle Shoals than to be continuously elected President of the United States."[2]

"The completed Muscle Shoals is worth more than all the gold currency in the world."[3]

"The destiny of the American people for centuries to come lies at Muscle Shoals."[4]

"America's Gibraltar—Muscle Shoals. In peace, prosperity for the farmer; in war, preparedness for the Nation."

"Muscle Shoals, waiting through the ages for man to tame their roaring waters and harness their mighty power."

"The Niagara of the South."

"Standards of living at stake in Muscle Shoals decision."

5. Characteristics of Tennessee River Drainage Basin. The area of the drainage basin supplying the Wilson Dam at Muscle Shoals is 30,800 sq. mi. Much of this is hilly or mountainous so that the rainfall falls on enough of a slope to produce a rapid run off from the surface of ground to the stream. Daily stream-flow readings for the Tennessee River, made at the railroad bridge at Florence, about 2½ mi. below the Wilson Dam and recorded by the U. S. Geological Survey, are available since 1871[5].

The average rainfall for the entire drainage basin is 51 in., of which 13 in. occurs in the winter, 15 in. in the spring, 14 in. in the summer, and 9 in. in the autumn.

6. Why Variable Stream Flow is Natural. Rainfall is the initial source of the water in all rivers. Rainfall is not continuous but periodic and varies largely with different seasons. Therefore, unless there is natural or artificial storage to equalize the volume, the flow of a river will vary approximately with the rainfall, Variable flow is obviously the natural condition of a river.

The Tennessee has neither natural or artificial storage at present and its variable flow characteristics are, therefore, typical, varying merely in degree with other rivers.

7. Characteristics of the Tennessee River. The banks of the Tennessee River are well cut, clearly defined and there has been little change, or tendency to change, in its course from year to year. The bottom of the river does not present any serious difficulties for dam foundations.

"The Tennessee is subject to sudden and frequent fluctuations in discharge. Its headwaters drain a mountainous region noted for heavy and prolonged rains and generally high annual precipitation. The high-water season is in the late winter and early spring and is caused by copious rainfalls, while the melting of snow, as a contributive factor, is only of minor significance.

"The maximum rates of flood flow in the Tennessee are not so high as might ordinarily be expected of a

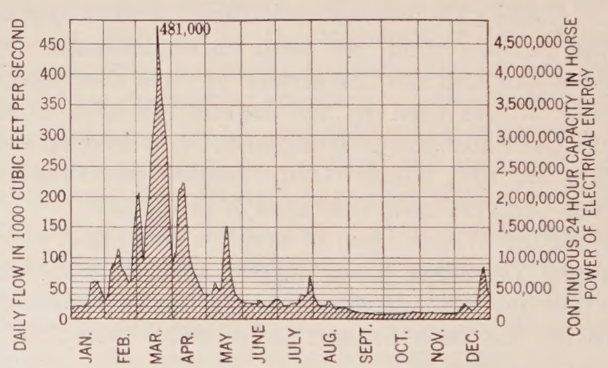

Fig. 3—Variation in Daily Flow and Horse Power of Tennessee River at Muscle Shoals

On the basis of 80 per cent. efficiency of the hydroelectric generators, 10 h. p. of electrical energy will be generated for each cubic foot per second flow at the Wilson Dam at Muscle Shoals. The scale at the right of figure shows h. p. capacity. (Left). Daily stream flow readings of Tennessee River at Florence, Ala., near the Wilson Dam, have been recorded by U. S. Geological Survey for 53 years. The data shown are for 1898.

river basin subject to the high rates of storm rainfall that are common there. This is attributable to three factors:

a. The peculiar configuration of the drainage basin which, near the middle, is constructed to a width of less than 40 mi.

b. The general westerly flow of the river in a direction contrary to the movement of storms.

1. Senate Document No. 83. 59th Congress, First Session.
2. Newton D. Baker.
3. Thomas A. Edison.
4. The New York Times credits this to Henry Ford.

5. Recorded in the U. S. Geological Survey Water Supply Papers Nos. 353, 383, 403, 433, 453, 473, 503.

c. The arrangement of the tributaries, which does not favor rapid collection and concentration of run off.

"On account of the mild winters, ice troubles, so common at hydroelectric plants in the northern United States and Canada, are rare and become a negligible factor in the operation of such installations in this region."[6]

8. *Variation in Daily Flow of Tennessee River.* This is shown in the yearly hydrograph chart on Fig. 3. In the extreme year shown—1898—the daily flow in "1000 cu. ft. per second" varied from 481 to 9, or 53 to 1.

In 1923, the daily flow varied in "1000 cu. ft. per second" from 215 to 8, or 27 to 1.

The maximum discharge of the Tennessee River recorded at Florence was 499 "1000 cu. ft. per second" and occurred on March 19, 1897.

It is important to bear in mind that these flow data are not deductions from rainfall statistics, but are actual measurements, and show the high and low flow conditions that must be coped with in water-power developments on this river.

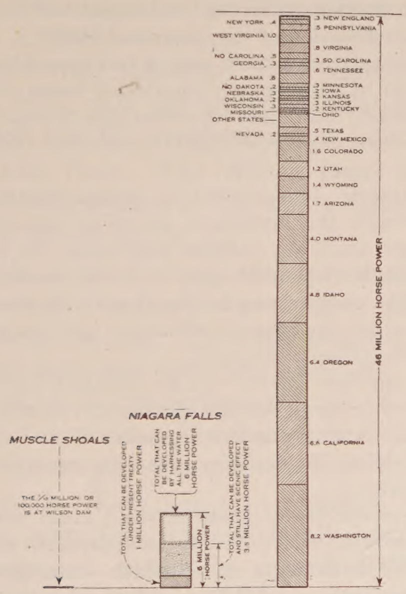

FIG. 4—MUSCLE SHOALS COMPARED WITH NIAGARA FALLS AND UNDEVELOPED WATER POWER IN UNITED STATES IN MILLION H. P.

The diagram at the right, the geographic distribution of potential undeveloped water power in United States, is based on data from the U. S. Geological Survey. This total is without artificial or stream flow control and is larger than it would be feasible to develop. Probably not over 25,000,000 h. p. will be worth developing for many years. The amount of power that may be alloted to the United States in any future joint development of the Niagara and St. Lawrence Rivers is not included.

The two comparisons above are for 24-hr. capacity without artificial or stream flow control; because of scenic preservation and ice flushing conditions, not more than three and one-half million h. p. can be depended upon at Niagara Falls.

The horse power that may be developed for various conditions of river flow at the Wilson Dam at Muscle Shoals, is shown at the right on Fig. 3.

9. *Water Storage Limitations.* At the Wilson Dam at Muscle Shoals, the area of the pool known as Wilson Lake is 14,500 acres, or in round numbers, 23 sq. mi. This pool gives enough ponding to meet daily fluctuations in loads but affords practically no storage.

10. *Meaning of "Primary Power" and "Secondary Power."* Primary power is the power that can be developed continuously for 24 hours of the day and for every day in the year. Secondary power is power that can be developed for merely a part of the time, and which may be for certain seasons of the year or for certain hours of the day only. The thing in which the ultimate consumer is interested is not primary power per se or secondary power per se, but continuous power; that is, continuity of service; and secondary power can be made continuous power only by having some other source of power to make up for the deficiency; this usually means a steam plant.

11. *Primary Power of Wilson Dam at Muscle Shoals.* In general, the primary power that may be depended upon at the Wilson Dam at Muscle Shoals is 100,000 h. p., continuous output. However, there will be occasional days when the primary power will drop to about 87,000 h. p. For the larger turbine capacity needed to utilize this primary power see §23.

12. *Secondary Power of Wilson Dam at Muscle Shoals.* In addition to the 100,000 h. p. of primary power that can be developed at the Wilson Dam, the following quantities of additional secondary power can be developed for the respective per cents of total time shown below for the two conditions of river flow shown:

Additional secondary horse power	Approximate per cent of total time available[7] Low year daily discharge basis	Mean monthy discharge basis
50,000	56 per cent	85 per cent
100,000	44 per cent	72 per cent
150,000	32 per cent	63 per cent
200,000	24 per cent	55 per cent
300,000	15 per cent	42 per cent

13. *Muscle Shoals Compared with Niagara Falls.*

	Muscle Shoals Wilson Dam	Niagara Falls[8]
Area drainage basin, square miles	30,800	263,400
Storage	none	1/3 area of drainage basin is water storage.
Head—that is, fall—that can be developed	95 ft.	300 ft.
Ice problem	none	Flushing the ice and maintaining scenic effect reduces the capacity from 6,000,000 h. p. to 3,500,000 h. p.
24 hour continuous capacity in horse power	100,000	3,500,000

Thus the continuous capacity that can be obtained from Muscle Shoals is 1/35 of the capacity of Niagara Falls, or it would take 35 Muscle Shoals to equal one Niagara Falls.

In using Niagara Falls as a comparative yard stick,

6. House Document No. 319, 67th Congress, Second Session.

7. House Document No. 1262, Plates 107 and 108, 64th Congress, First Session.

8. For further discussion see Smithsonian Institution Paper "Niagara Falls: Its Power Possibilities and Preservation."

it is important to bear in mind that the Niagara River is jointly owned by the United States and Canada and that the treaty limits the total development at present to 1,000,000 h. p. and there can be no further development until the treaty is amended. Furthermore, if the treaty is amended and the development is pushed to the limit—on the basis of still maintaining an adequate scenic effect—of 3,500,000 h. p., one-half of this, or 1,700,000 h. p., would belong to the United States.

14. Muscle Shoals Compared with Undeveloped Water Power in United States. While the potential undeveloped water power in the United States is, in round numbers, 46,000,000 h. p.—as shown in Fig. 4—probably not over 25,000,000 h. p., of this 24-hour continuous capacity without artificial storage, will be worth developing for many years. Therefore, the Wilson Dam at Muscle Shoals compares with this probable undeveloped water power, available for the near future, as follows:

Total undeveloped water power in the United States worth developing	25,000,000 h. p.
Wilson Dam at Muscle Shoals	100,000 h. p.

That is, the Wilson Dam at Muscle Shoals represents 1/250 of the undeveloped water-power capacity of the United States worth developing; or it would take 250 Wilson Dams to equal the undeveloped water power now worth developing in the United States.

15. Muscle Shoals Compared with Stationary Primary Power in United States.

Using the term primary power—as defined in Section 10—with the knowledge that the aggregate horse power capacity of all stationary steam, oil and gas engines, and steam and water turbines is in excess of 50,000,000 h. p. at the present time it is estimated that the strictly primary stationary horse power capacity in the United States is at least	40,000,000 h. p.
The primary power at the Wilson Dam at Muscle Shoals is	100,000 h. p.

That is, it would take 400 Muscle Shoals to furnish the primary stationary power that is now in use in the United States.

16. Water Power Possibilities of the Tennessee River Compared. The Wilson Dam is not the whole Muscle Shoals project, but merely a part of the proposed project; and this is but a small part of a much larger proposed development which Congress is now having studied; viz., that of the power-navigation-industrial possibilities of the entire Tennessee Basin.

The water-power possibilities of the Tennessee River compare as follows:

	Primary horse power
Undeveloped water power in the United States worth developing	25,000,000
United States share of total possible development at Niagara Falls	1,700,000
Probable total development on Tennessee River	1,000,000
Wilson Dam at Muscle Shoals	100,000

This shows that the proposed development on the Tennessee River is 1/25 of the probable power development in the United States and about 60 per cent of the United States' share of the total power that can be developed at Niagara Falls; and, further, that the present Wilson Dam development represents but one-tenth of the probable total Tennessee River development.

17. Water-Power Limitations.

1. Water power is not free. In the consideration of water power, many well meaning persons think only of the free gift of nature and entirely overlook the part that man's labor and money must necessarily play in the realization of the bounties of this gift. There seems to be an impression among some people that, since water runs down hill, water power can be developed at very little cost and with very little risk. Such an impression is, in most cases, very far from the truth. Water power is worth just what can be gotten out of it in competition with power manufactured from fuel.

2. While nature has made the water, it is no more natural or free than the nature-made coal. Both must be brought under control to be of service to man. "Much has been said about harnessing water falls. However, there has been little appreciation that someone must furnish the money for securing, maintaining and ultimately replacing the harness and hiring labor for the continuous direction of the harnessed energy."

3. Coal is relatively a small part of total power cost.

4. The cost of water-power plants per horse power of plant capacity is usually more than for steam plants, but the operating cost of a water-power plant should always be less than for a steam plant.

5. The capacity is dependent on stream fluctuation. With storage reservoirs, the maximum operating capacity is merely the average stream flow; without reservoirs, the maximum capacity that can be depended upon is merely the minimum flow. The flow of the stream may be injuriously affected by the operations of man or the agencies of nature and the available flow may be much less than anticipated.

6. While auxiliary plants can be installed to furnish power during the low water period,the increased cost would ordinarily not make this attractive in single plants.

7. Actual delivering capacity is usually much lower than the published figures.

8. Water-power development in the United States has been strewn with wrecks, due to failure to appreciate the clearly defined economic limitations under which water-power developments can take place and failure to cope with the nature-made limitations in variation in stream flow.

18. Proximity of Coal to Muscle Shoals. Extensive coal deposits are located in central Kentucky, central Tennessee and northwestern Alabama. These are, of course, advantageous from the viewpoint of furnishing fuel for any industries that would use Muscle Shoals power. These coal deposits, however, because of their proximity, make steam-power generation relatively easy and are, therefore, a determining factor in appraising Muscle Shoals power, since, in the long run, Muscle Shoals power is worth no more than power that can be generated from a steam plant.

19. Confusion of Power and Fertilizer. Much of the misunderstanding regarding Muscle Shoals arises from the confusion of the power project with nitrate production for either munitions or fertilizer. Power production must stand on its own feet and should be self-

sustaining; fertilizer production should also stand on its own feet and be self sustaining.

Fertilizer manufacture would require power. But there is no mysterious advantage whatsoever in Muscle Shoals power; power from any other source would function just as effectively. The crux is one of economic cost and not of mere geographical position.

II.—What has been Done to Date

20. History. "In 1824, J. C. Calhoun, Secretary of War, asserted that a canal around Muscle Shoals was of great national importance." The first investigation was authorized by Congress in 1828 and this was followed by others.

The first study "undertaken by the United States with a view to the possible development of the extensive potential water powers in this section of the river" was made in 1907. The whole project was finally brought to a head in the report of the Chief of Engineers, June 4, 1916,[9] describing the then-proposed dam construction, which later was named after President Wilson and officially designated the "Wilson Dam."

What is now known as the Wilson Dam was started November 9, 1918—two days before the armistice—but the work was suspsnded from April 15, 1921, to October 1, 1922, and the present indications are that the work will now be completed about January 1, 1926.

21. Wilson Dam. The Wilson Dam is located at the foot of Muscle Shoals, 2½ miles east of Florence, Alabama, as shown in Fig. 2.

The dam is a huge concrete structure with navigation locks at the north end, a power plant at the south end and a roadway on top. The total length of the structure is 4500 feet, and contains 1,350,000 cu. yds. of masonry, which is the largest volume of masonry in any dam in the world. The dam is 96 ft. high, 105 ft. thick at the base and rests on a hard blue limestone.

22. How the Work has been Handled. The entire project has been ably and efficiently handled by the War Department, under the general direction of the Chief of Engineers. All of the work has been done on a day labor basis and practically no contract work, except minor sub-contracts, has been used on the project.

23. Hydroelectric Power Plant. This is located at the southern end of the dam, and is in fact, an integral part of the main dam construction.

The power-house building is 1250 ft. long, 160 ft. wide and 134 ft. high, built of monolithic and reinforced concrete.

Four complete hydroelectric generators, each of 30,000 h. p., are now being installed, also four at 35,000 h. p. each. The room is large enough so that 10 additional units, each of 35,000 h. p. can be installed later.

9. Published as House Document No. 1262, 64th Congress, First Session.

The total installed capacity (above auxiliary equipment used in the plant itself) contracted for now is:

	Horse power
4 units, at 30,000 h. p. each	120,000
4 " " 35,000 " "	140,000
Present capacity	260,000
Additional units proposed:	
10 units, at 35,000 h.p. each	350,000
Proposed future capacity	610,000

However, not all of the 260,000 h. p. of installed capacity is available for continuous use for the reasons given in the next paragraph.

While the stream-flow conditions will permit of a continuous output of but 100,000 h. p., the demands for electric energy are not uniformly distributed over the 24 hours and the maximum hour would ordinarily be 50 per cent more than the average hour, so that 150,000 h. p. of turbine capacity would be required to meet the probable daily peak of the primary horse power serving capacity. One unit should be in reserve and ready to at all times take care of any break down in operating machines.

The additional equipment which is for secondary power can be used in general only, as arrangements are made for getting some other source of power to supplement the low stream flow periods.

24. Navigation Locks. Two navigation locks, each having a lift of 46-ft. 6-in., are a part of the north end of the Wilson Dam. The depth available in each lock is 7½ ft.

25. Highway Bridge. The extreme top of the dam structure will be used as a public highway bridge and arrangements will be made so that the Lee and Jackson Highways, now going into Florence, will connect with this bridge.

26. No. 1 Dam for Navigation. This is located near the railroad bridge at Florence, as shown on the map, Plate 2. It is about 15 feet high and by means of a lock with a 10-ft. lift, will connect to the Wilson Dam locks by a canal about 2½ miles long on the north side of the Tennessee River. This dam will be used for navigation only.

The cost of this is entirely separate and in addition to the figures given for the Wilson Dam in the next section, it is estimated at $1,600,000.

27. Estimated Cost of the Wilson Dam. The total amount of money spent directly on the Wilson Dam up to March 1, 1925, was $38,340,822. The total cost of completing the dam and installing four 30,000-h. p. units and four 35,000-h. p. units, with all auxiliary equipment—see Sections 29 and 30—is estimated at $45,800,000.[10]

28. Wilson Dam Built with Borrowed Money. The

10. The estimated cost of the additional ten 35,000-h. p. units or a total of 350 000 h. p., is $5 323,000.

United States Government, in order to get money to build the dam, sold bonds to a large number of private individuals. In this way, money that was earned and saved by private individuals was borrowed by the United States Government on a rental or interest basis and mobilized; that is, these individual savings were put to work collectively in building this project. In this way, the government hired capital just as it hired labor, and the rental of the money is just as much a part of the cost of the dam as the hire of the labor. Furthermore, in order to ultimately return the money borrowed from the individual owners, provision should be made within the period of the useful life of the property so that enough money will be set aside out of the income from the project to ultimately pay back the money to private owners from whom it was borrowed.

29. Omitted Cost Items. The estimate in paragraph 27 has not included all items of cost that must ultimately come out of the public treasury. In addition to the appropriations for building the dam, there is:

a. The money used for paying for the material and labor has been borrowed for a number of years and the government has been paying interest on this amount. The total interest during construction, which must come out of the public treasury, up to the completion of the dam, January 1, 1926, is, in round numbers....................	$4,000,000
b. Preliminary engineering service in the survey upon which the construction work was based, about........................	150,000
c. Services of the Army Engineers, who have directed the work, paid out of the public treasury and therefore chargeable to this work................................	150,000
	$4,300,000

30. Cost of Wilson Dam to the Public. Taking the estimated cost of $45,800,000, plus the omitted cost items in the preceding section, $4,300,000, we get a total cost to the public of the Wilson Dam of $50,110,000

In the more than six years since the construction work on this dam was started, the United States Government has purchased construction equipment which is a part of the above dam cost. If the No. 3 Dam is built at once, a part of this equipment can be used for the additional work. If the No. 3 Dam is not built, then this equipment may be sold or transferred to another job and the Wilson Dam cost should be credited with whatever can be realized from such sale or transfer. It has been impossible to reconcile the widely divergent views as to the credit that could be allowed for this equipment. For the purposes of comparison, an allowance of $1,000,000 is made as a credit to the Wilson Dam cost, thus making the net cost in round numbers to the public on the Wilson Dam, $49,000,000.

31. Wilson Dam Cost Compared with Steam Plant Cost.

Taking the total cost given in the preceding section for the Wilson Dam as $49,000,000, and with the frank recognition that this gives but 100,000 h. p. of primary power, we at once get an investment cost per horse power of plant capacity of............	$490.00
The per horse power cost per actual primary horse power output of a high grade steam plant, with $^1/_5$ of the capacity in reserve at all times to guard against break down to insure continuity of service, would be........	100.00

The additional secondary power that can be generated at Muscle Shoals will, of course, be of service but it can be of service only as it is combined with other plants, which will keep the combined capital investment above a single steam plant.

32. Navigation's Share of Wilson Dam Cost. The water-power development of the Wilson Dam at Muscle Shoals is not sufficiently attractive to subsidize navigation. The comparative cost figures given in the preceding section indicate the financial handicap for this water power project, so far as investment is concerned.

It has been suggested that 25 per cent of the total cost could be charged to navigation, but it must be remembered that this would be merely a bookkeeping transfer and would, in no way, change the blunt fact that the public must ultimately foot the entire bill, for, under our present navigation policy, the contribution would come out of the public treasury and not from the people who benefit directly by the navigation advantages.

33. Real Estate Speculation. There naturally has been an abnormal real estate boom in the Muscle Shoals district. Detailed records of 109 subdivisions totalling 48,381 lots and aggregating 6750 acres or 10.7 sq. mi. area, were examined. This is merely part of the development and some of the allotments are indicated on Fig. 2.

Alluring but deceptive advertising matter has been persistently and widely circulated; lots have been sold to widely scattered buyers. Many of these allotments are in corn fields or pasture land, and practically all are without improvements other than a few graded dirt streets and cheaply constructed sidewalks. Twelve miles distant from the Wilson Dam is not an uncommon location for these additions that are advertised as being right at Muscle Shoals.

34. Origin of Public Misconceptions about Muscle Shoals. We have a wide gap between current popular beliefs regarding Muscle Shoals and the fundamental facts because:

1. The narcotic and hypnotic effect of superlative terms, like those cited in Section 4, used repeatedly, has produced a distorted perspective.

2. As a nation, we have been more interested in debating than in fact-finding, fact-recording, and fact-facing. There has been all too little appreciation that while slogans may change beliefs and mental attitudes, they never can alter facts. Imagination plays an important role in our national life. To many, symbols are the same as realities and the symbol rather than the reality aspect has been stressed at Muscle Shoals.

3. The current newspaper expression of "white coal" for water power is creating an erroneous idea as to the value of water power and the public has jumped to the unwarranted conclusion that when you have a water power, you are getting something for nothing. Deflation of many of our water power ideas is desirable.

4. There is nothing magical about water power and it is worth just whatever can be obtained from it in competition with coal,—and no more.

5. Even though the Muscle Shoals dam is the largest concrete monolith and the largest dam in the world, mere size of structure—that is, volume of masonry—does not make power. Water power requires water fall and continuity of flow and has been much over-estimated at Muscle Shoals.

6. Optimism run wild in real estate development has not only disseminated many erroneous statements but has secured the financial interest of a large number of individuals scattered all over the United States in the unwarranted real estate developments which have tended to still further mislead the public as to the possibilities that might be realized at Muscle Shoals.

III—What can be Done at Muscle Shoals

35. Possible Future Dams. The map on Fig. 1 shows the locations of possibly twelve future dams that may be built in the Tennessee River drainage basin. "Examinations made of the rocks which will be used show that excellent foundations can be obtained throughout this region."[11] The aggregate primary horse power that can be developed at the twelve future dam sites shown, is 751,000. In addition, the Cove Creek Dam would make a storage reservoir from which some regulation of stream flow can be secured and this would increase the primary horse power capacity at the present Wilson Dam and Hale's Bar Dam.

The estimated cost of these twelve dams is $125,000,000. The land that would have to be condemned aggregates 109,000 acres; and the above estimated cost has allowed $30,000,000 for land acquisition. Obviously, any tendency on the part of the present land owners to hold up prices could easily so increase the cost as to make future projects from this aspect alone undesirable from a business viewpoint.

36. Tennessee River Power Possibilities. The 100,000 primary h. p. capacity of the present Wilson Dam at Muscle Shoals plus the 751,000 primary horse power of the proposed 12 dams, referred to in the preceding section, plus the increase in primary horse power capacity that regulated stream flow would produce in the present Wilson and Hale's Bar Dams, would give a primary horse power capacity of the Tennessee River, in round numbers, of 1,000,000 horse power.

37. Navigation Aspects. Building the additional dams would give satisfactory navigation conditions for this part of the river, however, there still would be a stretch between the Riverton Dam going north to the mouth of the Tennessee River at Paducah that needs improvement.

38. Muscle Shoals a Mere Incident in the Tennessee River. From the preceding, especially in paragraph 35, it is obvious that Muscle Shoals is a mere incident in the Tennessee River development program and it must be evaluated from this viewpoint.

39. United States Government's Position at Completion of Wilson Dam. Toward the end of this year, when the Wilson Dam will be completed, the United States Government will be in the position of having about $49,000,000 invested in a water power project that can be depended upon for 100,000 primary horse power, but will be without transmission lines or a market. That is, the Muscle Shoals power project will be "all dressed up and no place to go."

The secondary power at Muscle Shoals can be made available only as it can be combined by transmission lines with other power sources.

40. United States Government Steam Plant. An excellent steam plant was built at Nitrate Plant No. 2 in 1918. It contains a 60,000-kw. steam turbine in three elements, of 80,000 h. p. capacity.[12] It is in good physical shape and could be used for supplementing the secondary power of the Wilson Dam.

41. Common Sense on Fertilizer Situation.[13] Fertilizer will be made by fixing the nitrogen of the air or any other process whenever it is good business to do so; that is, when the process can be carried on at a fair profit. No sane man would go into an enterprise unless it could be carried on at a profit. In other words, the same motive that prompts the farmer to expend labor and capital in raising a crop (which is merely getting a living wage or return for labor and capital) will insure the manufacturer of fertilizer. It is no more wicked for a fertilizer manufacturer to make a fair profit than for a farmer to make a fair profit. Without profit there is no incentive; without incentive, there can be no progress.

The fixation of nitrogen is a long way from fertilizer. To compare the cost of segregated nitrogen at Muscle Shoals before its proper combination with other ingredients to make usable fertilizer, is not unlike comparing the cost of raw wool with the cost after it becomes a suit.

42. U. S. Nitrate Plant No. 1. This was an experimental synthetic ammonia plant. It never operated, and, as it now stands, is not of interest for commercial production. It probably would be cheaper to construct a new plant than to redesign and rebuild Plant No. 1 to permit of its competing with plants based upon the latest developments. This represents an investment of about $12,000,000.

43. U. S. Nitrate Plant No. 2. This is constructed to operate on the cyanamid process, which won its place because it requires less than one-fourth the power necessary for the earlier, but now out of date, arc process and because the raw materials—coal, limestone,

11. Wilbur A. Nelson, State Geologist, Nashville, Tennessee.

12. One horse power is equal to 0.746 kw., or one kilowatt is equal to 1.34 h. p.

13. For further discussion see Part 3 "The Air-Nitrogen Processes"—U. S. Department of Commerce, Trade Information Bulletin No. 240.

and nitrogen—are obtainable in many places. The synthetic ammonia process is rapidly rendering the cyanamid process commercially obsolete as a method for fixing atmospheric nitrogen for fertilizer purposes. It uses less than one-third of the power required for the cyanamid process and this power need not be electric energy. Progress in the synthetic ammonia process makes the cost of pure hydrogen, and not power, the controlling economic factor. This plant, including the Waco Quarry, represents an investment of about $67,000,000.

44. Future Market for Muscle Shoals Power. Electric power has completely revolutionized industrial living and social conditions in parts of the South. In Alabama, east Tennessee, Georgia, and the Carolinas, hydro power is largely employed in various industrial and textile activities. Western Tennessee and practically all of Mississippi have already been touched and are waiting for this development program.

The absence of income or inheritance taxes in Alabama and other taxation inducements, make this state an exceptionally favorable one for the investment of capital for carrying on industrial activities.

Abundant reserves of non-migratory, reliable, English speaking, intelligent, white labor, accustomed to simple living and living close to food supplies with small fuel needs for house heating and lack of labor concentration with attendant housing problems, give the South an advantageous mill labor situation for converting its raw cotton into the finished product right in the South, providing dependable and continuous electric power service is availale.

The shortened transportation of the raw cotton, by finishing the product in the South, is, of course, also advantageous.

The southern negro, living here in his natural and normal habitat, employed extensively for common labor, because of his tractability, is rarely susceptible to the disturbing influence common where the foreign element dominates the labor field, and is a distinct labor asset for the heavier tasks.

The South is growing rapidly and there has been a marked exodus of the cotton industry from the New England states to the South. The number of wage earners, the annual million pounds of cotton manufactured, number of active spindles, and primary horse power employed in cotton industry is increasing much faster in the southern states than in the north.

The per cent of cotton produced, that is, converted into the manufactured product is for:

Mississippi	5 per cent
Louisiana	13 per cent
Tennessee	31 per cent
Alabama	44 per cent
Georgia	111 per cent
North Carolina	141 per cent
South Carolina	174 per cent

That is, the last three states are fabricating more cotton than they are producing and are, therefore, importing from other producing states, due primarily to the advantageous labor and electric power conditions.

Within the limits of the Tennessee River Basin and where power will be required for development, at least 50 mineral substances of economic value are found.

"Special emphasis should be placed on the large phosphate deposits of middle Tennessee; the extensive coal fields of northern Alabama and eastern Tennessee; the fine ball clays of western Tennessee, which are used in making electrical insulators and other high-grade articles; the great marble copper mines at Ducktown; the unlimited deposits of limestone of the purest quality, suitable for making high grade lime and other similar uses; to the iron ores of Alabama and Tennessee and the bauxite deposits of eastern Tennessee and northern Georgia."[14]

Securing lower labor and lower production costs is, of course, of vital interest to the public at large. There has been all too little appreciation of the fact that every man's wage is a part of some other man's cost of living.

"It therefore appears that a broad and well-founded judgment would dictate that the Muscle Shoals development should be interconnected for exchange of power with the existing power systems of the Southern States, and that this interconnection and exchange should be arranged for without delay, so that future construction, both at Muscle Shoals and elsewhere, can be directed for the production of plants which will supplement each other for economy of construction and operation."[15]

In conclusion, within easy transmitting distance from Muscle Shoals, there is an adequate, existing, electric-power market that can promptly absorb all of the electric power that can be developed. This market can be economically reached and effectively served only as Muscle Shoals is made part of an integrated, interconnected transmission system, so that advantageously located steam plants and storage reservoirs can be used for supplementing the otherwise practically valueless secondary power at Muscle Shoals.

STATE TECHNICAL INSTITUTE PROPOSED

Lewis A. Wilson, director of the division of vocational and extension education in the New York State Department of Education, has prepared a pamphlet on "The Need for a State Technical Institute," the result of ten years' study. The proposed institute would contain departments of industrial information, chemical and physical research, statistical research, factory construction, accounting and business methods, trade and technical training and management training. It would further research work and provide full-time courses of two years or longer, shorter full-time courses, cooperative courses, evening and correspondence courses along technical and trade lines.

14. Wilbur A. Nelson, State Geologist, Nashville, Tennessee.
15. War Department Document No. 1039, Office Chief Engineer, "The Power Situation During the War." p. 267.

Over-Voltage on Transmission Systems Due to Dropping of Load

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Associate, A. I. E. E.

***Synopsis:**—When a waterwheel-driven generator, or a hydroelectric station, loses all or a large part of its load, the voltage rises more rapidly and to a greater extent than has been generally realized.*

The purpose of this paper is to show the manner in which the voltage will rise under different conditions, and a method of calculating the voltage rise of a waterwheel-driven generator when load is lost.

The results of a large number of tests are given showing the rise in voltage on an 8500-kv-a., 6600-volt waterwheel generator when load was tripped under several different conditions at three different places, namely; at the generator, on the high-voltage side of a transformer bank, and at a substation forty miles away.

As it is not considered good practise to subject a transmission system to high over-voltages, consideration is given to methods of checking the voltage rise by use of relays as soon as possible after load has been dropped.

MUCH has been written about instantaneous rises of voltage due to switching surges, and transients due to short circuits, but very little has been said regarding the rise of voltage due to dropping of load on an a-c. system.

Great interest has been shown in various sections of the country during the past year in the voltage obtained when a waterwheel-driven generator, or a hydroelectric station, loses all or a large part of its load, since voltages obtained in this manner are much higher and develop more rapidly than would ordinarily be expected.

When load is lost on an a-c. generator, or group of a-c. generators, the manner in which the voltage rises and the time interval taken for such a rise varies according to the following factors:

1. Voltage regulation and design of the generator.
2. Type and speed regulation of prime mover connected to generator.
3. Generator excitation obtained from direct-connected exciter, exciter motor-generator set, or d-c. bus.
4. Amount and power factor of load dropped.
5. Voltage regulators used or not used.
6. Place in circuit where load is tripped.
7. Connections including lines, transformers, etc., between generator and load.
8. Over-voltage or over-speed devices used or not used.

With the above points in mind, calculations were made to determine the maximum rise in voltage on ordinary waterwheel-driven generators when load was lost under different conditions. The results of these calculations are shown in Table I. Details regarding method of making calculations are given later.

In order to check the calculations and to obtain further information, a series of tests[2] were made, in which load was dropped in different ways and under many different conditions on an 8500-kv-a., three-phase, 60-cycle, 164-rev. per min., 6600-volt, 80-per cent power-factor waterwheel generator, connected to a large 60-cycle system, through an 18,000-kv-a. bank of transformers and a 40-mile, 66,000-volt transmission line.

TABLE NO. I
VOLTAGE RISE IN PER CENT OF NORMAL VOLTAGE

Type of Prime Mover	Over-Speed	With Voltage Regulator		Without Voltage Regulator	
		With direct-connected Exciter	Without direct-connected Exciter	With direct-connected Exciter	Without direct-connected Exciter
Water-turbine....	25–35%	50–80%	40–65%	90–100%	60–85%

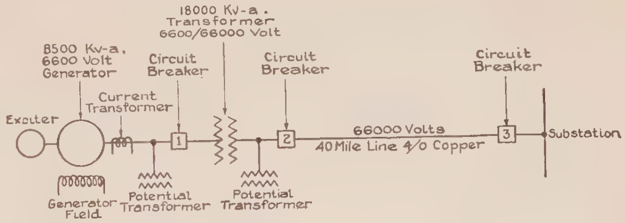


FIG. 1—ARRANGEMENT OF EQUIPMENT FOR TEST

Connections and arrangement of equipment between the generator and substation are shown by Fig. 1. By use of circuit breakers, 1, 2 and 3, load could be tripped at any one of three different places. These circuit breakers will be referred to as generator, transformer-high-voltage, and substation circuit breakers, respectively.

The generator had a direct-connected exciter, but in order to also make tests with the generator separately excited, a temporary connection was made to a small, waterwheel-driven exciter. However, the limited capacity of this exciter would permit the generator when separately excited to carry only 4000-kw. load at 98 per cent power factor.

A vibrating type, 60-cycle voltage regulator was in the station, so plans were made to use that in some of the tests.

Connections were made to an oscillograph so that

1. Central Station Engineering Dept., General Electric Company, Schenectady, New York.

2. Tests were taken at the Spier Falls Station of the Adirondack Power & Light Corporation.

Presented at Regional Meeting of Dist. No. 1, Swampscott, Mass., May 7-9, 1925, and to be presented at the Annual Convention of the A. I. E. E., Saratoga Springs, N. Y., June 22-26, 1925.

TABLE II

Test	Oscillogram	Load dropped-kw.	Power Factor per cent	Direct-connected Exciter	Regulator	Over-voltage Relay	Over-Frequency Relay	Breaker tripped by Hand	Breaker tripped by Relay	Maximum Voltage in per cent of normal
1	97300	5900	83	Yes	No	No	No	1	–	195
2	97304	6100	83	Yes	Yes	No	No	1	–	151
3	97325	4000	98	No	No	No	No	1	–	128
4	97321	6500	83	Yes	No	No	No	2	–	174
5	97313	6400	90	Yes	Yes	No	No	2	–	157
6	97312	6400	90	Yes	No	No	No	2	–	185
7	97317	6700	83	Yes	No	No	No	3	–	218
8	97323	6100	87	Yes	Yes	No	No	3	–	168
9	97322	6500	83	Yes	Yes	Yes	No	2	1	113
10	97324	6150	83	Yes	Yes	No	Yes	2	1	126
11	97318	6700	83	Yes	No	Yes	No	3	2	183
12	97319	6700	83	Yes	No	Yes	No	3	1	201
13	97310	3500	70	Yes	No	Yes	Yes	2	1	138
14	97320	6700	83	Yes	Yes	No	No	3	–	206
15	97309	3500	66	Yes	No	Yes	No	2	1	138

any three of the following waves could be recorded at the same time:

1. 60-cycle or 40-cycle timing wave.
2. Generator field or exciter voltage.
3. Generator current.
4. Generator voltage.
5. High-tension voltage at a point between transformer and transformer high-voltage circuit breaker.

Table II gives details regarding tests in which load was dropped in different ways and under different conditions.

It will be noted that 6700 kw. was the largest load dropped. The generator could not carry a greater load that this because of the water conditions at the time the tests were made.

Commercial load was used for these tests; therefore, because of the system operating conditions, it was not always possible to drop the load most desirable for a particular test. However, by giving consideration to the amount of load dropped, proper comparisons may always be made between the different tests.

It will also be noted that after a load was dropped, in some cases the speed rise reached 152 per cent of normal, which is a much greater speed increase than generally obtained on waterwheels under similar conditions. This large speed increase is accounted for by the fact that the waterwheel governor had not received final adjustment, but this does not make the tests less valuable, since the speed characteristics for each test can be determined by making a comparison between the timing wave and the generator-voltage wave. Furthermore, the large speed regulation of the waterwheel was offset, to some extent, by the load dropped, which was less than normal; therefore, the results are not far from what might ordinarily be expected, as will be shown later.

Load Dropped by Tripping Generator Breaker Direct-Connected Exciter Used

Fig. 2 shows the results of two tests, a voltage regulator being used in Case 2, but not in Case 1. Curves 1 A and 2 A show the rise in speed that took place as soon as load was dropped. Curves 1 B and 2 B show the corresponding rise in generator voltage.

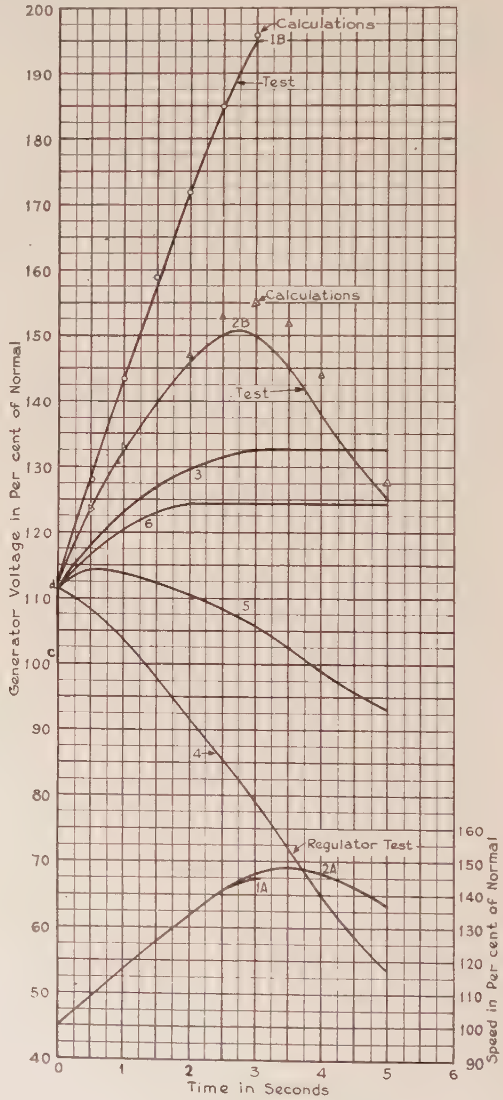


Fig. 2—Case 1. 5900-kw. Load Dropped by Tripping Generator Breaker. Direct-Connected Exciter. No Regulator

Case 2. 6100-kw. Load Dropped by Tripping Generator Breaker. Direct-Connected Exciter. Regulator in Operation

The curves illustrate that as soon as the generator breaker was tripped, the generator voltage rose instantly to approximately 112 per cent of normal, and then increased in accordance with Curve 1 *B* or 2 *B*, 1 *B* being without voltage regulator and 2 *B* being with voltage regulator. The effectiveness of the voltage regulator is plainly seen when a comparison is made between Curves 1 *B* and 2 *B*. The maximum over-speed is greater in Case 2 than in Case 1, as shown by speed Curves 2 *A* and 1 *A*, due to the fact that a slightly larger amount of load was dropped in Case 2 than in Case 1.

Referring to Case 1, Fig. 2, the solid line, 1 *B*, represents test values as recorded on an oscillogram, while the small circles were plotted from calculations. In Case 2, solid line 2 *B* represents test values, while the small triangles are taken from calculations. The method by which the calculations were made will be given later.

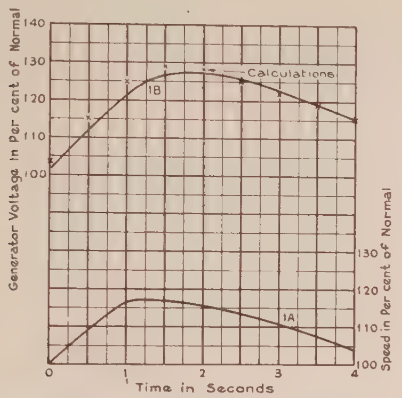


Fig. 3—4000-kw. Load Dropped by Tripping Generator Breaker. Generator Separately Excited. No Regulator

Load Dropped by Tripping Generator Breaker Generator Separately Excited

Results of a test in which the generator was separately excited are shown in Fig. 3. As only 4000-kw. load was dropped, the speed did not rise as high as it did in tests previously described.

After the load was dropped, the voltage increased in accordance with Curve 1 *B*. The small crosses represent points calculated.

Load Dropped by Tripping High-Voltage Transformer Breaker Direct-Connected Exciter Used

Fig. 4 shows results of two tests, one taken with and one without voltage regulator. In each case, load was dropped by opening the high-voltage transformer breaker. Here, as before, the voltage regulator was very effective in limiting the rise of voltage.

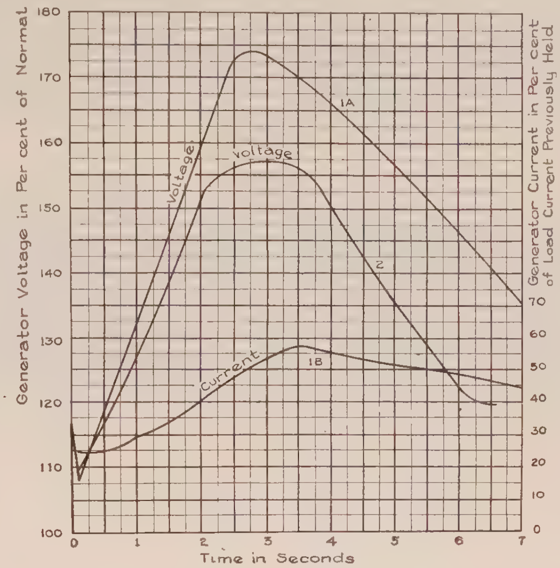
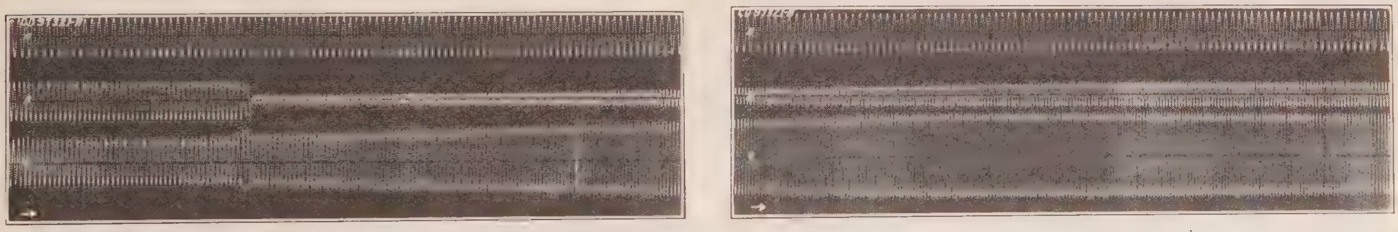


Fig. 4—Case 1. 6500-kw. Load Dropped by Tripping Transformer High-Voltage Breaker. Direct-Connected Exciter. No Regulator

Case 2. 6400-kw. Load Dropped by Tripping Transformer High-Voltage Breaker. Direct-Connected Exciter. Regulator in Operation

Allowing for the different amounts of load dropped, it is seen that when the load was tripped by the transformer high-voltage circuit breaker, the voltage did not rise as high as when the load was tripped by the generator circuit breaker. This difference was due to the exciting current taken by the transformer after the high-voltage circuit breaker had been opened, which was load current for the generator. Curve 1 *B*, Fig. 4, shows how the transformer exciting current, or in other words, the generator-load current, increased as the voltage became greater and greater after load had been dropped.

Figs. 5A–B show part of the oscillogram from



Figs. 5A-B—6500-kw. Load Dropped by Tripping Transformer High-Voltage Breaker. Direct-Connected Exciter. No Regulator

Curve *A*—40-cycle timing wave Curve *B*—Generator current
Curve *C*—Generator voltage

which Curves 1 *A* and 1 *B*, Fig. 4, were taken. The oscillogram shows how the transformer exciting current and the generator voltage increased in value after load was dropped, the middle wave being transformer exciting current and the lower wave generator voltage.

Fig. 6 shows part of an oscillogram similar to that of Fig. 5A, with the exception that a slightly different load was dropped. The middle wave indicates exciter voltage instead of generator current. This middle wave gives a good indication of how the exciter voltage increased in value as the speed increased, after the load was dropped.

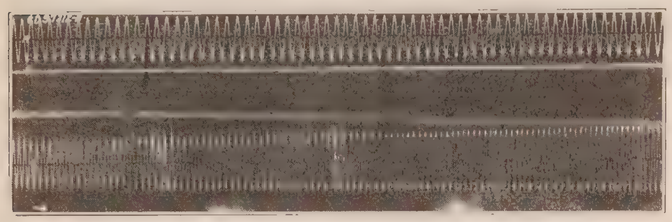


FIG. 6—6400-KW. LOAD DROPPED BY TRIPPING TRANSFORMER HIGH-VOLTAGE BREAKER. DIRECT-CONNECTED EXCITER. NO REGULATOR

Curve *A*—40-cycle timing wave
Curve *B*—Exciter voltage
Curve *C*—Generator voltage

LOAD DROPPED BY TRIPPING SUBSTATION BREAKER DIRECT-CONNECTED EXCITER USED

Fig. 7 shows the results of two tests, one taken with and one taken without voltage regulator, in which load was dropped by opening substation circuit breaker. The voltage regulator was again very effective in limiting the voltage rise.

Curve 1 of Fig. 7 shows a 118 per cent voltage rise, which is a greater rise than obtained in any of the tests. This is only natural when consideration is given to the fact that the charging current of the 40-mile line more than offset the exciting current of the transformer, the effect of which was to boost the excitation of the generator.

Curve 2 *B*, Fig. 7, shows the generator current which is a resultant of transformer exciting current and line-charging current. In this instance, the current curve has two peak values, the dip in the middle occurring at the time the voltage reached maximum.

Figs. 8A–B show parts of the oscillogram from which Curves 2*A* and 2*B* of Fig. 7 were taken. The middle wave of the oscillogram shows clearly the dip in the generator currents mentioned above, and also the many harmonics in the current wave. The lower wave of the oscillogram represents the generator voltage and shows the switching surge at the time the high-voltage transformer circuit breaker was tripped, and just how the voltage increased after the load was tripped.

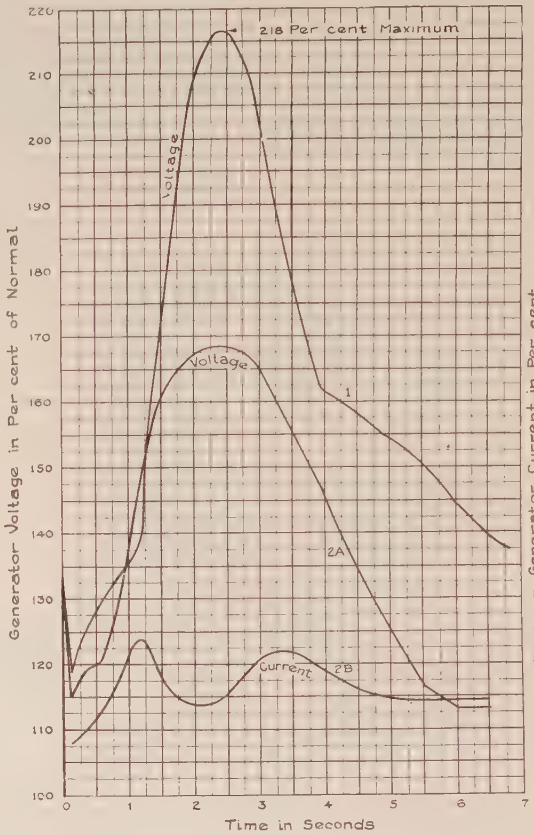
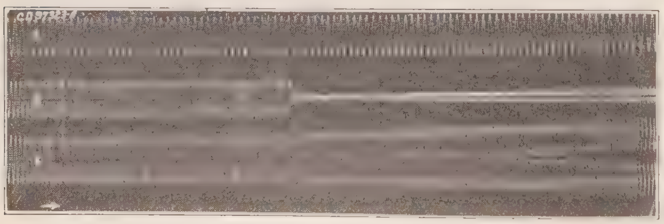
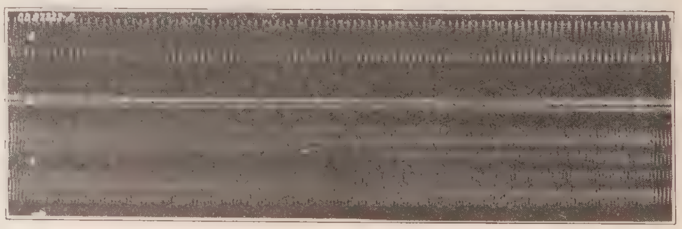


FIG. 7—CASE 1. 6700-KW. LOAD DROPPED BY TRIPPING SUBSTATION BREAKER. DIRECT-CONNECTED EXCITER. NO REGULATOR.

CASE 2. 6100-KW. LOAD DROPPED BY TRIPPING SUBSTATION BREAKER. DIRECT-CONNECTED EXCITER. REGULATOR IN OPERATION





FIGS. 8A-B—6100-KW. LOAD DROPPED BY TRIPPING SUBSTATION BREAKER. DIRECT-CONNECTED EXCITER. REGULATOR IN OPERATION

Curve *A*—40-cycle timing wave
Curve *B*—Generator current
Curve *C*—Generator voltage

Voltage Reduction

The tests already described show the rapid and extensive rise of voltage that occurs when load is lost on a waterwheel-driven generator. Believing it desirable to check the voltage rise as soon as possible after load is dropped, a series of tests was made to determine the speed with which the generator open-circuit voltage could be reduced by three different methods. A tabulation covering these tests is given in Table III. Fig. 9 shows the results of three of these tests, each method being represented. Curve *a* shows the rate of voltage decrease when a block of resistance was placed in the exciter field circuit, this being accomplished by holding the voltage regulator contacts open. Curve *b* shows the rate of voltage decrease when the exciter field switch was opened, and Curve *c* the rate of voltage decrease when the generator field circuit breaker was tripped. Field discharge resistors were, of course, used in the two later cases.

TABLE NO. III
REDUCTION IN GENERATOR OPEN-CIRCUIT VOLTAGE

Test	Oscillo-gram	Previous Voltage in % of Normal	Method of Reducing Voltage	Time in Seconds for Voltage to decrease 50%
16	97302	143	Insert Resistance in Exciter Field Circuit	4.75
17	97306	149	Open Exciter Field Switch	3.75
18	97305	52	Trip Generator Field Breaker	0.90
19	97316	100	Trip Generator Field Breaker	1.00

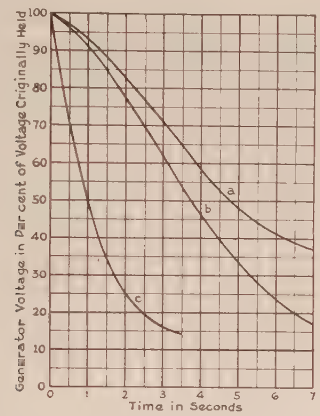


Fig. 9—Generator Open-Circuit Voltage Decreased:
Case *a*: by Inserting Resistance in Exciter Field Circuit
Case *b*: by Opening Exciter Field Switch
Case *c*: by Tripping Generator Field Circuit Breaker

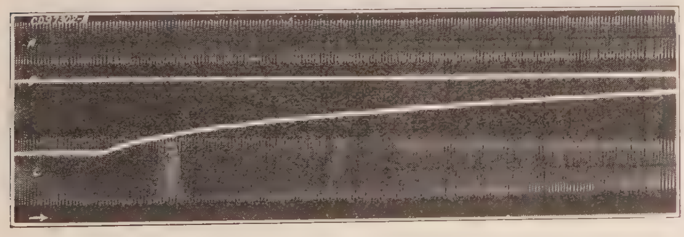


Fig. 10—Generator Open-Circuit Voltage Decreased by Inserting Resistance in Exciter Field Circuit
Curve *A*—60-cycle timing wave
Curve *B*—Exciter voltage
Curve *C*—Generator voltage

Fig. 9 shows the advantage of tripping the generator

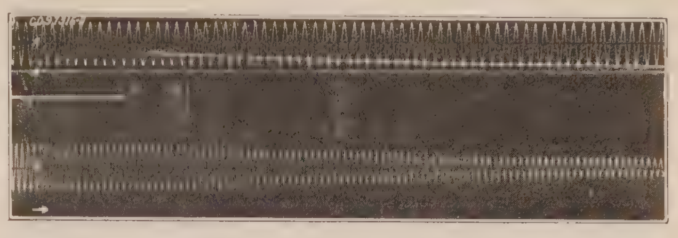


Fig. 11—Generator Open-Circuit Voltage Decreased by Tripping Generator Field Circuit Breaker
Curve *A*—40-cycle timing wave
Curve *B*—Generator field voltage
Curve *C*—Generator voltage

field when it is desirable to reduce the generator voltage at a very fast rate.

Fig. 10 shows the oscillogram from which Curve *a* of Fig. 9 was taken. The middle wave of oscillogram shows the way the exciter voltage decreased when a block of resistance was placed in the exciter field circuit.

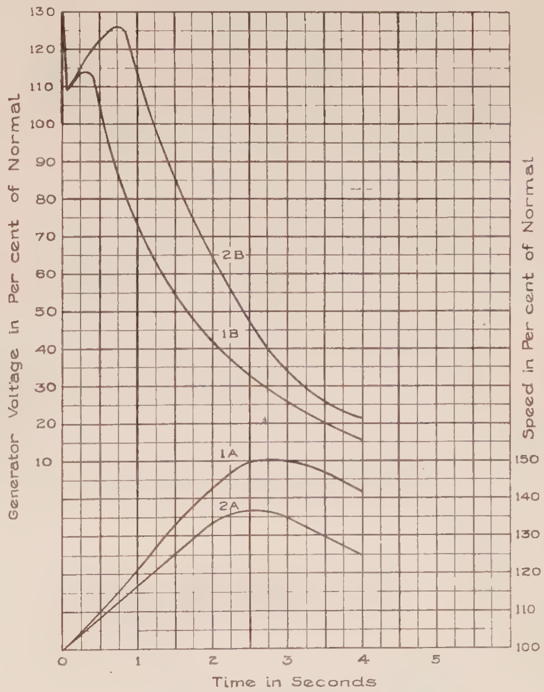


Fig. 12—Case 1. 6500-kw. Load Dropped by Tripping Transformer High-Voltage Breaker. Direct-Connected Exciter. Regulator in Operation. Over-Voltage Relay Tripped Generator Breaker
Case 2. 6150-kw. Load Dropped by Tripping Transformer High-Voltage Breaker. Direct-Connected Exciter. Regulator in Operation. Over-Frequency Relay Tripped Generator Breaker

Fig. 11 shows the oscillogram from which Curve *c* of Fig. 9 was taken, the generator field circuit breaker

being tripped at a time when the generator was operating at normal voltage, no load. The middle wave of oscillogram shows how the generator field voltage decreased after the field circuit breaker was opened. It will be noted that the generator field excitation was reversed in polarity at the time the field circuit breaker was tripped.

Fig. 12 shows the effect of tripping the generator field circuit breaker, as well as the generator main circuit breaker, after load had been dropped by opening high-voltage transformer circuit breaker by hand.

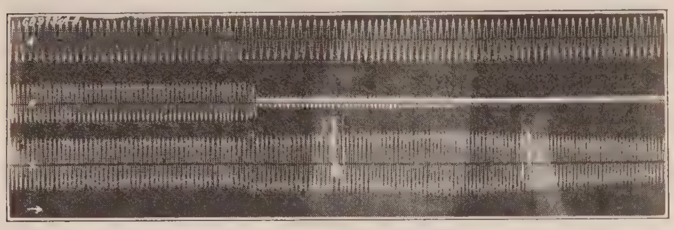


FIG. 13—6150-KW. LOAD DROPPED BY TRIPPING TRANSFORMER HIGH-VOLTAGE BREAKER. DIRECT-CONNECTED EXCITER. REGULATOR IN OPERATION. OVER-FREQUENCY RELAY TRIPPED GENERATOR BREAKER

Curve *A*—40-cycle timing wave
Curve *B*—Generator current
Curve *C*—Generator voltage

Curves 1 *A* and 2 *A* show the rise in speed and Curves 1 *B* and 2 *B* show the corresponding voltage changes, when load was dropped. The difference in the two speed curves is due to the fact that more load was dropped in Case 1 than in Case 2.

Voltage Curves 1 *B* and 2 *B* are also different. In Case 1, the generator and field circuit breakers were tripped by an over-voltage relay set at 115.5 per cent of normal voltage. In Case 2, the generator and field circuit breakers were tripped by an over-frequency relay set at 63 cycles or 105 per cent of normal frequency. In each case, auxiliary contactors were used with the relays so arranged that the trip circuits of the generators and field circuit breakers would be energized at the same time.

OVER-VOLTAGE AND OVER-FREQUENCY RELAYS

The curves in Fig. 12 give information regarding the operation of the relays, as well as information regarding the voltage and speed changes. In Case 1, the generator and field circuit breakers were tripped sooner than in Case 2. This was due to the fact that the over-voltage relay in Case 1 was operated by the initial voltage impulse which reached approximately 130 per cent of normal, while the over-voltage relay in Case 2 did not operate until approximately a quarter of a second later when the speed reached 105 per cent of normal.

Fig. 13 shows part of the oscillogram from which Curves 2 *A* and 2 *B* of Fig. 12 were taken. The middle wave on the oscillogram represents the generator current and indicates clearly the time when the high-voltage transformer circuit breaker opened and also the time when the generator circuit breaker opened. By use of the 40-cycle timing wave, it is found that the generator circuit breaker opened approximately 0.73

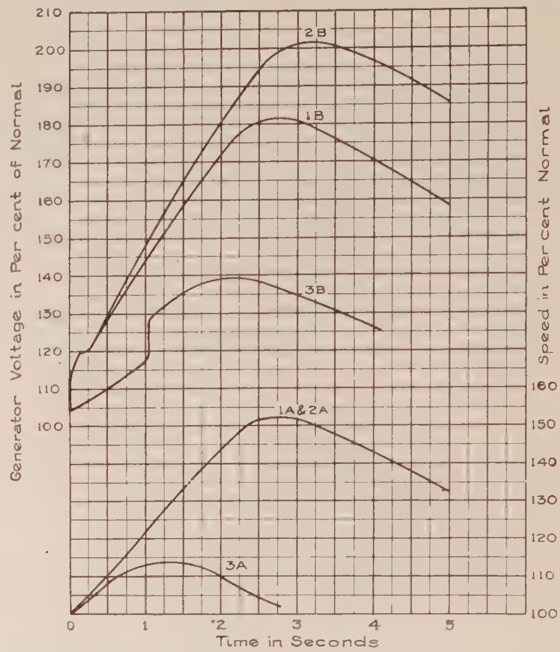


FIG. 14—CASE 1. 6700-KW. LOAD DROPPED BY TRIPPING SUBSTATION BREAKER. DIRECT-CONNECTED EXCITER. NO REGULATOR. OVER-VOLTAGE RELAY TRIPPED TRANSFORMER HIGH-VOLTAGE BREAKER

CASE 2. 6700-KW. LOAD DROPPED BY TRIPPING SUBSTATION BREAKER. DIRECT-CONNECTED EXCITER. NO REGULATOR. OVER-VOLTAGE RELAY TRIPPED GENERATOR BREAKER.

CASE 3. 3500-KW. LOAD DROPPED BY TRIPPING TRANSFORMER HIGH-VOLTAGE BREAKER. DIRECT-CONNECTED EXCITER. NO REGULATOR. COMBINATION OVER-VOLTAGE AND OVER-FREQUENCY RELAY TRIPPED GENERATOR BREAKER

seconds after the high-voltage transformer circuit breaker was tripped.

Three different tests are represented in Fig. 14. An over-voltage relay was used in Case 1 and Case 2, but

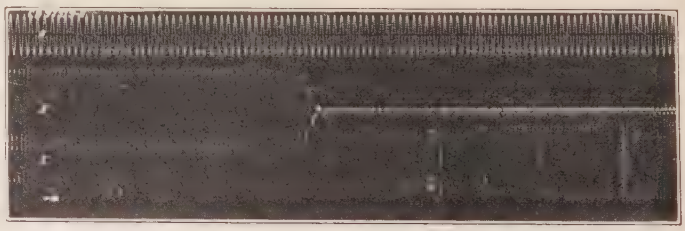


FIG. 15—6700-KW. LOAD DROPPED BY TRIPPING SUBSTATION BREAKER. DIRECT-CONNECTED EXCITER. NO REGULATOR. OVER-VOLTAGE RELAY TRIPPED GENERATOR BREAKER

Curve *A*—40-cycle timing wave
Curve *B*—High-tension voltage at transformer terminals
Curve *C*—Generator voltage

in Case 3, a combination relay of both over-voltage and over-frequency was used. In the latter case, the over-voltage element was set at 115 per cent normal voltage and the over-frequency element was set at 105 per cent

normal frequency. The contacts of both elements were placed in series, so the tripping circuit of the generator breaker would not be energized until each set of contacts had been closed. An analysis of the curves shows that the contacts of the over-voltage relay closed approximately 0.5 seconds later than the closing of the over-frequency relay contacts.

In Case 1, the relay tripped the high-voltage transformer circuit breaker, while in Case 2, the relay tripped the generator circuit breaker. In Case 1, the transformer exciting current furnished load for the generator; therefore, the voltage did not rise as high as it did in Case 2, where the generator had no load after the generator breaker was tripped.

Fig. 15 shows part of the oscillogram from which Curve 2 *B* of Fig. 14 is taken. The middle wave of the oscillogram represents the voltage on the high-voltage side of the transformer. The small voltage indicated after the generator breaker was opened was induced from a 110,000-volt, 60-cycle line, which parallelled the line being used for these tests.

Generator Circuit Breaker and Relay Tests

In order to check the operation of the relays, two tests were made with the use of the oscillograph, one to determine the operating time of the generator circuit breaker and the other to determine the operating time of the over-voltage relay. The results of the tests are shown in Table IV.

TABLE IV
OPERATING TIME
GENERATOR CIRCUIT BREAKER AND OVER-VOLTAGE RELAY

Test	Oscillogram	Equipment	Operating Time Seconds
20	97314	Generator Breaker and Relay	0.21
21	97315	Generator Breaker	0.11

General Considerations and Calculations

Voltage Regulation. Due to regulation, the voltage of an a-c. generator carrying full load at normal speed and voltage will generally rise between 25 and 35 per cent above normal when load is lost, providing the speed and excitation remain constant.

Part of this rise in voltage is instantaneous and part takes place over an interval of time. Consider the 8500-kv-a., 6600-volt a-c. generator used in the tests just described, and assume that it is carrying a load of 5900 kw., 0.83 per cent power factor, as in test No. 1.

When carrying this load, the calculated internal or generated voltage is equal to 111 per cent of the terminal voltage. The internal voltage differs from the terminal voltage by the amount of impedance drop in the stator winding. If the load just mentioned is dropped, the terminal voltage will instantly rise to a value equal to the internal voltage because the flux to produce this voltage is already present in the stator and because the impedance drop in the stator winding disappears as soon as load is dropped. Referring to Fig. 2, this instantaneous voltage rise is shown by line *c d*, the calculated value being 111 per cent and the test value being 112 per cent of normal voltage.

Using calculations and assuming, further, that the speed and excitation remain constant, the voltage will increase from 111 per cent voltage to the open-circuit voltage. This rise of voltage is shown by Curve 6, Fig. 2, and takes place over an interval of time, because after load is tripped and armature reaction disappears, time is consumed in building the stator flux up to a value corresponding to the field m. m. f.

For an average generator on which full load is lost, this time may be assumed to be two seconds, but varies to some extent, according to the size and design of the machine in question.

Prime Mover. As the governors of waterwheels and steam turbines are speed devices, a change in load is always accompanied by a change in speed. Given sufficient time, the new output of energy will be produced at a new steady speed. (Only by readjustment of the governor can the new output be produced at the previous speed.) When the decrease of load is great and sudden, the speed will rise higher than the ultimate speed, this over-shooting being due to the inability of the governor system to follow quickly enough the speed of the turbine rotor.

The overspeed of water turbines when full load is lost varies according to the horse power of the turbine, the time taken to close the guide vanes, the $W R^2$ of combined generator and turbine unit, the rev. per min., and the length of penstocks. However, these different factors combine in such a way that for an ordinary design of water turbine, the overspeed is usually between 25 and 35 per cent when load is dropped.

Fig. 16 shows some typical speed-time curves indicating the rise in speed on a large water turbine when different amounts of load were dropped. In this particular case, the speed rose to 131.5 per cent of normal, when full load was dropped.

In the tests referred to in the first part of this article, the speed regulation was greater than customary for the reason already given, namely: the waterwheel governor had not received final adjustment.

The maximum speed attained by a steam turbine when load is suddenly removed is much less than that attained by a water turbine under similar conditions.

Tests taken on a 30,000-kw. steam turbine show that when full load was dropped the governor action was such that the maximum speed attained was only four per cent above normal. This maximum speed was reached in one second. Upon dropping a 75 per cent load on the same turbine a maximum speed rise of 2.75 per cent normal was attained in 0.9 seconds. Even if the emergency governor of a steam turbine is called upon to operate, the speed will generally not rise above 110 per cent of normal.

In view of the foregoing, the danger from the over-

voltage on steam stations is not as great as on hydroelectric stations.

Generator Excitation. Field excitation for a-c. generators is generally obtained by one of the following methods:

1. D-c. bus.
2. Direct-connected exciter.
3. Exciter motor-generator set.

The maximum over-voltage obtained when load is dropped depends, to some extent, on which method of excitation is used, as a direct-connected exciter will

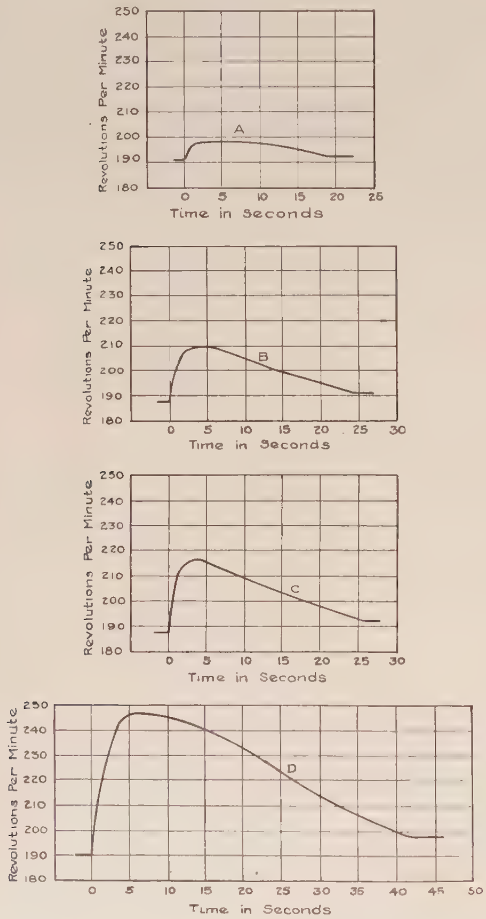


FIG. 16—LOAD REJECTION ON A 44,000-KW. WATER TURBINE
Case *A*— 39.8 per cent load dropped
Case *B*— 58.0 per cent load dropped
Case *C*— 67.0 per cent load dropped
Case *D*—100.0 per cent load dropped

overspeed with the generator when load is dropped. The same is true of an exciter motor-generator set if the motor of the set receives power from a circuit connected to the a-c. generator which loses load.

An increase in the speed of the exciter causes an increase in the exciter voltage, which, in turn, causes an increase in the a-c. generator field current and, therefore, a further rise in the a-c. generator voltage.

For exciters generally used, the armature voltage increases approximately as the square of the speed, as the speed is increased above normal. The a-c. generator field current increases in direct proportion to the increase in exciter voltage providing the resistance in the field circuit remains the same, but the a-c. generator voltage will not increase in direct proportion to the increase in field current due to saturation of the iron in the generator magnetic circuit. However, if a waterwheel-driven generator, having a direct-connected exciter, drops load, the field current will rise to such an extent that the open-circuit voltage will usually reach the upper part of the saturation curve, which is nearly flat.

Referring again to Fig. 2, the voltage rise shown by Curve 6 assumes no increase in speed when load is dropped, and assumes the generator to be separately excited. If the speed is increased and field excitation held constant, the voltage will actually rise above this Curve 6 in direct proportion to the increase in speed. This is true because the open-circuit voltage of an a-c. generator is always proportional to the generator speed, providing the excitation remains constant.

Now assume that the 8500-kv-a. generator has a direct-connected exciter and that it is connected to a waterwheel having a speed characteristic as shown by Curve 1 *A*, Fig. 2. Curve 3, Fig. 2, shows how the generator voltage increases to 132.5 per cent of normal assuming an overspeed on the exciter, but no over-speed on the generator. (This is a physical impossibility, but is suggested as a step toward determining the actual voltage). Instantaneous increase in voltage *c d* is the same as before. For the voltage rise indicated by Curve 3, a time lag of three seconds has been assumed, which takes into consideration the lag of flux change in both the exciter and the a-c. generator.

When the load is dropped, the generator, as well as the exciter, overspeeds; therefore, the calculation of the actual generator voltage curve for this condition involves increasing the value of the voltage points on Curve 3, in accordance with the increase in speed, as shown on speed Curve 1 *A*. The resulting calculated values of actual generator voltage are indicated by the circle points falling on or near Curve 1 *B*.

Voltage Regulators. In case a generator voltage regulator is used in connection with a generator that loses load, the regulator will, of course, try to keep the voltage from rising. As soon as load is lost, the regulator contacts at once open and a block of resistance is inserted in the exciter field circuit. If a large amount of load is dropped on a waterwheel-driven generator, the generator voltage rises in spite of the fact that a block of resistance has been placed in the exciter field circuit, principally because flux change in the exciter and the generator is relatively slower than the speed change.

Curve *A* of Fig. 9 represents a voltage regulator test, as already mentioned. This curve is reproduced in Curve 4 of Fig. 2 for use in making calculations. For convenience, the starting point of the curve is raised to 111 per cent generator voltage and all other points are raised in the same proportion.

It was previously stated that Curve 3 of Fig. 2 shows how the generator voltage increases, assuming an over-speed on the exciter, but no over-speed on the generator. By combining Curve 3 and Curve 4, a resultant curve is obtained, as shown by Curve 5, which represents approximately the change in voltage when a load of 6100 kw., 0.83 power factor is dropped, a direct-connected exciter and a voltage regulator being used.

Curve 3 is used to take care of a 6100-kw. drop of load, as well as a 5900-kw. drop of load, because, if two curves were plotted, one would fall practically on the other. Now, increasing the voltage points on Curve 5, in accordance with the increase of speed, as shown by Curve 2 *A*, final calculated results are obtained as shown on the small triangles. These calculated points fall reasonably close to the test Curve 2 *B*.

Amount and Power Factor of Load Dropped. The per cent voltage regulation of a generator and the per cent speed regulation of a turbine being greater for full load than for part load, it is obvious that the loss of full load on a generator will cause a greater rise in voltage than dropping part load.

As the power factor of a load being furnished by a generator is decreased below unity (assuming constant kw. output), the field excitation, the kv-a. output, and the internal generated voltage increase. Therefore, the lower the power factor of the load dropped, the greater will be the rise in voltage.

Conclusions

It is not considered good practise to subject a transmission system to high over-voltages, especially if they are of long duration, because such over-voltage might cause damage to the generators, motors, transformers, lightning arresters, lines, insulators and other equipment connected to the system.

Each piece of apparatus is designed for a particular maximum voltage, should be tested in accordance with A. I. E. E. Standardization Rules, and should operate continuously and successfully at that voltage under normal operating conditions. If the voltage is increased above normal, apparatus or equipment may or may not fail, according to the following factors:

1. Maximum over-voltage obtained.
2. Duration of over-voltage, taking into consideration the speed with which the voltage is increased or decreased.
3. Factor of safety in insulation and design of apparatus or equipment.

In other words, the time element of over-voltage must be taken into consideration as well as the maximum overvoltage. For example, a piece of apparatus may withstand an impulse voltage of double normal or more, when the duration of the impulse is a fraction of a cycle, but may fail if subjected to a voltage of much less value when applied continuously for several seconds at normal frequency.

In general, it is desirable to design any piece of apparatus so that it has as high a factor of safety against failure as is consistent with an economical design. The proper balance between factor of safety and economy of design depends largely on the principle underlying the design. In some kinds of apparatus, such as transformers, a high factor of safety is possible; in others, as lightning arresters, the same high degree of safety with over-voltage is incompatible with the proper function of the device.

An attempt should never be made to capitalize the factor of safety by operating a piece of apparatus at voltages above normal. Furthermore, it should not be assumed that the factor of safety will take care of any over-voltage that may exist momentarily on a system.

Although the apparatus treated thus may not fail immediately, the insulation or other parts may be weakened, so that by repeating or continuing the conditions of over-voltage, eventual failure is invited.

Total loss of load, and therefore dangerous over-voltage, may occur on any hydroelectric station having only one or two outgoing lines. If all, or nearly all of the power, is fed out from the station over one line, then in case of trouble it is quite possible that load on this line will be lost, particularly if the line is adequately protected by relays. If a station has two outgoing lines, both line breakers may occasionally trip automatically; also, if two outgoing lines are used, one line may be under repair, in which case, all of the power would be transmitted over the second line. The situation would then be the same as though only one line existed.

When the load is fed out over three or more lines, there is much less likelihood of complete loss of load; therefore, the same precautions are not as essential as in the case of stations having only one or two circuits.

The contact of the over-speed and the over-voltage relays may be connected either in multiple or in series. If they are connected in multiple, the over-voltage relay should be given a sufficiently high setting to prevent it operating in case of ordinary switching surges. If the contacts are connected in series, the over-voltage, as well as the over-speed relay, may be given a rather low setting.

CONSTRUCTION OF AUSTRIAN HYDROELECTRIC PLANT

The Tyrolese Hydroelectric Power Co., a joint-stock company of which the majority stock is held by the City of Innsbruck, has obtained a loan of $3,000,000, for the development of its Achensee power plant. This loan will enable the development of 70,000 horse power by 1927 and it is planned that the plant will eventually be enlarged to develop 100,000 horse power. The power generated will be sold to the Federal Railways for the Kufstein-Innsbruck line, to existing neighboring industries, and to the City of Innsbruck for such requirements as the municipal power plant is unable to accommodate.—(Trade Commissioner Elbert Baldwin, Vienna.)

Automatic Control for Substation Apparatus

BY WALTER H. MILLAN[1]

Member, A I. E. E.

Synopsis.—*The use of automatically operated stations has become quite general over the country, but as the development has been very rapid, and the engineers involved so busy with their individual problems, very little has been accomplished toward the pooling of ideas and experiences.*

This paper outlines some of the more important problems being encountered in automatic development such as the need for automatic fire protection in the stations, the necessary future development of thermal protective devices, voltage regulating devices, etc. Particular stress is laid on the fact that, while we have some problems which we presume have been worked out, some of the solutions are far from perfect.

This paper is prepared in a manner which, it is hoped, will bring out many valuable ideas in its discussion.

THE engineering profession has been presented with many papers and reports covering the field of automatic operation, but in almost every case an attempt has been made to describe some particular installation and, as is most natural, the author, whether manufacturer or operator, brings out all of the clever and agreeable points that he can find. This is very creditable but it is felt that the development has reached a stage where the injection of some pessimism would seem to inspire faster progress. The highest developed is the railway class, being the first to be attempted. This class rapidly came to its present high state of development, principally because of its simplicity. In railway operation, very low load factors are encountered thus avoiding, at least to some extent, temperature troubles with their attending ventilating problems. Also, voltage regulation is more or less rough and distribution system resistance high, lowering the precision required in regulating devices and making parallel operation of machines and stations fairly easy.

The next highest developed is the alternating-current transforming and distributing substation. Again we have simplicity, in that there are comparatively few functions, the operation of which actually had to be automatized; the balance being only a matter of finding sufficient courage to close and lock the doors on equipment which had previously been operated with an attendant to watch it. We have had the automatic induction regulator for a good many years but always with someone close by, and while there is no reason why it should not be trusted to operate without a guardian, the author confesses that he had some very anxious hours during the first few weeks of such operation of equipment for which he was responsible. There are only three other automatic operations of a major nature in the average station of this class: First, the automatic switching of supply circuits, not hard to accomplish unless automatic synchronizing is required: Second, the automatic reclosing of distribution circuits on trouble, which detail varies in complexity with the class of service. At the outside, the problem requires the application of only four or five relays or devices per three-phase feeder over and above the standard apparatus which would be present if the station had an attendant. The third is water control and is present only where transformers and similar equipment is operated "water cooled" over peak-load periods. This is a simple function and is usually given a passing glance only notwithstanding the fact that it is of the highest importance.

The third and least developed class is that of supply stations to heavy Edison system networks where extremely low system resistance is encountered, close precision is called for in voltage regulation and an interruption to service is an unpardonable offense. The author will not attempt to discuss weak points in the automatic railway station field as he is not qualified to do so from the standpoint of experience. Therefore, the following discussion will cover the other two classes only.

Class 2—Automatic A-C. Distribution and Transformer Stations

There are a great many of these stations in successful operation and almost every one of them has some specific points, good as well as unique. Usually these points are emphasized almost to the exclusion of others of equal importance; for example, we may find a station in which a great deal of effort and money has been concentrated on the automatic operation of its supply circuits to prevent the possible loss of supply power due to failure of supply circuit. This is accomplished by automatic transfer devices to keep power on the station bus as long as one of its supply circuits is alive. In the same station we may find only a single transformer unit supplying several important distribution feeders, no provision having been made to save the day if, by any chance, the transformer should fail. Frequently this transformer depends on cooling water to carry it over the peak and we find that there is but one source of water supply; or, if there are two, they are not automatically "changed" in event of failure. The conventional way to protect such a transformer against sustained overload is by means of the well known thermal relay which is supposed to possess the same relative heating and radiating characteristics as the transformer, and so adjusted that full load amperes will permit the unit to stay on

1. Union Electric Light & Power Co., St. Louis, Mo.

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continuously but approximately 25 per cent in excess of this amount tripping the transformer off the line in thirty minutes. The exact principle of the operation of this device is usually only partially understood by the man who actually locates it in the station and upon this point depends its real utility. To be consistent, this thermal relay must undergo exactly the same abuse and benefits regarding ventilation that the transformer suffers and it can be seen that, should the thermal relay be so located that its heat is dissipated by a draught of cold air from a ventilator or by conduction to a wall on which it may be mounted, it may fail to protect the transformer. The manufacturers have recognized this liability and generally provide a thermostat submerged in the transformer oil, which trips off and locks out the transformer if the oil exceeds about 85 deg. cent. This would probably save the transformer (but not the service) if the overload was approached slowly so that too great a drop in temperature between the "hot spot" and the oil was not in evidence, but, if a sudden overload appears after many hours of very light load, when the oil has cooled to a very low temperature, the oil with which the "hot oil" thermostat is in contact may be 50 deg. cooler than the "hot spot" and the thermostat quite useless should the thermal relay fail to function. The above would indicate that we should attempt to develop a means of direct relaying from the actual, measured, hot spot temperature rather than try, by means of a proportional auxiliary circuit, to imitate the performance of the transformer. Much may be said about thermostats. The average operating engineer notes in the specifications that a thermostat will stand guard over his transformer and he accepts this face value. He may, in fact, for years possess many of these devices embedded in his apparatus without ever having actually seen one of them. Without injustice to the electrical manufacturers, it may be said that we should not expect them to know as much about building these devices as do the manufacturers of heating and ventilating apparatus. The author has found that these latter manufacturers possess equipment of this nature directly applicable to our needs which has been developed and in successful operation for years. When applied to transformers, thermostats are usually mounted on some projection on the head block or core, and this means that the transformer must be taken out of service and the oil lowered to get at them for test purposes. With "conservator" or "inertaire" types of transformers, where the case lid is tightly sealed, this becomes an expensive matter and as a result the thermostats once installed are not tested. We attacked this problem some months ago and, as a result, we are installing in many St. Louis station transformers, thermostats made by a well-known manufacturer of heating apparatus who knew nothing of the possible applications to this field. These thermostats are no closer to the "hot spot" than their predecessors—(that being another problem)—but they may be removed and tested without even taking the transformer off the line. This applies to the "sealed" types of transformers as well as others.

The control of cooling water, so far as the thermostat is concerned, is also partly solved by the above, but, automatically operated water valves have not been given sufficient attention. The author has had experience with two types of valves which are furnished by the electrical manufacturers,—the motor operated type and the type which is operated by the expansion and contraction of a gas or fluid in a capillary tube. In his opinion, the latter type is dangerous, as a leak in the pressure system renders the device inoperative without visible indication of trouble until it fails to operate,—and perhaps the load lost. The motor-operated valve, of course, depends upon the continuity of the wiring and the 100 per cent behavior of the motor, which is usually small and operates through a reduction gear, the friction of which is a large percentage of the total power required. The author's experiences with both of the above types have been unhappy, in that both types have failed to function on many occasions, resulting (fortunately in one case only) in the loss of 5000 kw. of distribution load for about one hour. A water valve has been made up of standard materials; this by means of current flowing through a solenoid, holds the water off. The opening of the circuit to the solenoid by the thermostat allows the law of gravity to turn the water on. This device is in effect a closed circuit one and accidents (electrical or mechanical), can result only in wasted water. Some of these devices have been in operation in St. Louis for two years without a failure and almost all station transformers, under the writer's jurisdiction, either have been or are being equipped with this type of valve.

No attempt has been made to protect against failure of induction regulators for distribution circuits, other than to depend on the overload relays to clear them from the line when failure actually occurs. The induction regulator is admittedly a weak piece of apparatus because of its very nature; and it would seem advisable to take steps to give them at least temperature protection. There is a tendency on the part of the operating companies to allow their distribution feeders to become overloaded and, with regulators designed for a 55-deg. rise, this abuses the regulator. The failure of an induction regulator in a manual station may not be serious when an operator who can operate a fire extinguisher is present, but here, again, in the automatic station, we have in most cases failed to provide any protection against fire except faith. Automatic equipment possesses only the intelligence which is incorporated in its design and this falls short of human intelligence in that we have not as yet been able to give it all five of the human senses. It can only *feel* but does not possess the senses of smell, taste, hearing or sight. In manual stations many serious accidents have been forestalled by the operator's ability to "smell something getting hot,"

hear the growl of an arc or *see* smoke issuing from a piece of apparatus the protective devices for which have not *felt* the necessity of removing it from the line; that necessity not being felt until the trouble has developed into a short-circuit, which usually means fire. In general, while this class of station may be said to be satisfactory, it is obvious that there is still a very extensive field in which to progress.

Class 3—Automatic D-C. Substations Feeding Heavy Edison Networks

This class has been developed mostly along the lines of single-unit stations consisting of a motor-generator set or synchronous converter located here and there throughout systems, the major portion of the system being manually operated. This means that the automatic stations are merely followers supplying power to parts of the net-work which grew out of the original manual capacity. In systems of over 30,000 or 40,000 kw. cases where automatic stations are the predominating factors are extremely rare; if, in fact, there are any at all. Where the system is so heavy, it is usually of high density and this in turn means not only a large number of stations but stations of such capacity that several large units per station are necessary. With these large stations close together, parallel operation begins to present a problem. To begin with, the demand upon the operating attendants in the manual stations of such a system is that they hold the "standard feeder-end pressure" to within one volt (0.5 volt per side). There is a reason for this other than the required candle power of customer's lamps, and it is a fact that by lowering or raising the voltage in a station one volt from standard, upwards of 1000 kw. of the load will be shifted to and from adjacent stations. The writer has been unable to find on the market an automatic regulating device which could be applied to this class of service and which might be adjusted to give closer than 1.5 volts, plus or minus (a zone of three volts) on on the 240-volt basis. It is obvious that then the stations would not only not give sufficiently close regulation but would be continually "stealing" load from each other. It might be possible, of course, by means of costly pilot circuits to prevent the load from shifting, but we would still lack the precision in voltage regulation at the customer's lamp. On voltage regulators it would seem that some intensive development is necessary. The voltage regulator being the keynote to this situation, too much stress cannot be placed on this point. The question of parallel operation of any number of machines in the same station is being worked upon and there seems to be no doubt that all obstacles will ultimately be overcome; not however, without doing some things that have never been done before. It is always possible to make each machine literally an isolated station by feeding directly into the system over its own feeders, but it means that all copper is not working on light loads unless some extra money is invested in heavy bus tie breakers and, after all, it is dodging the main problem. While the apparent "intelligence" of some of the d-c. automatics now in service, is remarkable, we are still relying too much upon pilot wires and periodical inspection to approach the intelligence of an operating attendant. We must remember that automatic equipment will do just the things we build it to do and, incidentally, keep on doing them even if dangerous to life or property. In other words, it cannot use judgment, change its mind nor respond to the dictates of fear. This means that the equipment comprising an automatic station must be rugged in every detail. For example, it would not be desirable to protect all d-c. circuit-breakers with temperature devices and they should therefore be selected so as to allow ample margin. Based on actual experience, the author feels that no d-c. circuit-breaker in this class of service should be operated at a contact brush density of more than 350 amperes per sq. in. If heavier duty is imposed it is possible for a breaker to heat up so quickly that its bridges will be annealed before this is discovered. The author advocates the use of "maximum" thermometers the fluid columns of which remain at the highest point reached unless shaken down intentionally. One of these thermometers on the contact block of each breaker will divulge, to the inspector, the value of the highest temperature reached during his absence and an oxidized contact can be caught before the critical point (annealing) is reached. This same idea may be applied to bearings, as the only protection they now have is through the medium of a gas type thermostat by which the machine is locked out when a dangerous temperature is reached on any of the bearings. Ventilating equipment is another factor that should be fortified with ample margin and ruggedness, as in most cases the station cannot operate unless its ventilating equipment is delivering. Again the "maximum" thermometer is useful, as it can be applied to the machine and outside temperatures in conjunction with recording load-indicating devices to determine if the equipment has been properly cooled in the absence of the inspector and a brewing case of trouble arrested. The method of tripping oil and air circuit-breakers and contactors is one that should have close attention. There is a tendency to employ, so far as possible, standard breakers which almost always are held in by a mechanical latch or toggle. This must be struck sharply by the tripping solenoid to actually open the main device. Breakers furnished for standard manual application have been known to fail to trip on the first impulse of the tripping solenoid and as there is no attendant in an automatic station to follow up and trip it manually, this breaker remains closed. The author feels that a holding-in type of latch should be used in these applications, as it does not depend on the continuity of an electrical circuit for its operation. In some cases this is not possible, as in the case of automatizing an existing station already equipped. We have partly solved this problem

by the application of two relays in the tripping circuit, so connected that if the main device does not open at the first impulse, it is followed up by a succession of hammer blows which will either open the toggle or break it, in which latter case the main device, although broken, would be opened. Too much stress cannot be brought to bear on the matter of auxiliary switches on the mechanisms of all types of breakers. Originally these switches were for the sole purpose of operating indicating lamps and an occasional interlock. In an automatic station there is hardly an operating circuit that does not interlock through the auxiliary switch of some breaker or contactor and it follows that the failure of almost any of these auxiliary switches will cripple the station. The author has had some bad experiences with this equipment, both where existing devices were automatized and where the equipment was furnished specifically for automatic operation.

General

While the author feels that progress is being made, there is still too much of a tendency to be satisfied with some questionable equipment as its exists. It is necessary that we look further into the future and in solving the problems which we encounter as we go along, bear in mind the importance to always leave sufficient margin so that that particular thing will be forever placed behind us.

A New Two-Phase to Six-Phase Transformer
Connection of One Hundred Per cent Apparatus Economy

BY A. BOYAJIAN[1]

Member, A. I. E. E.

Synopsis.—*A new transformer connection of 100 per cent apparatus economy is described for transformation from two-phase to six-phase and vice versa. Its merits from various standpoints are compared with those of the Scott and the Woodbridge connections.*

Introduction

This paper describes a new two-phase to six-phase transformer connection which has an "apparatus economy" of one hundred per cent.

By apparatus economy is meant the ratio of the single-phase transformer kv-a. rating of the device to its kv-a. rating as a phase transformer. This ratio is sometimes called "internal power factor." This latter term, however, is not so good, because of the fact that, although at unity power factor loads the value of the internal power factor is identically the same as the apparatus economy, yet the internal power factor varies with the load power factor, while the apparatus economy is independent of the load power factor.

Description of the Connection

Fig. 1 shows the connection diagrammatically.

The core and flux are two-phase, so that two single-phase cores or one two-phase core would be necessary and sufficient.

Considering the windings, two windings are needed on the two-phase side, one for each phase. They may be interconnected (as T, L, or diametrically), or they may be entirely independent. This freedom is advantageous in being adaptable to any two-phase system.

On the six-phase side, we have a rectangle, $B\,C\,E\,F$. crossed by the line $A\,D$. The voltages of the various parts are shown in the illustration.

1. Of the General Electric Company, Pittsfield, Mass.

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It may be noted that the six-phase side may also be considered a diametric three-phase system, since any diametric three-phase device may be operated from it.

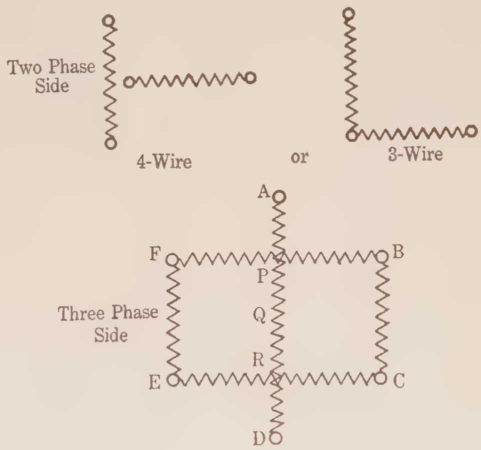

Fig. 1—Two-Phase to Diametric Three-Phase or Six-Phase Transformers

Three-phase side:
- Voltages: AD—BE—CF—100 per cent
- AP—PQ—QR—RD—25 per cent
- BC—PR—FE—50 per cent
- BP—PF—CR—RE—43.3 per cent

Currents in Lines—100 per cent
- Current in AP—PQ—QR—RD—100 per cent
- " " BC—FE—50 per cent
- " " BP—PF—CR—RE—86.6 per cent

New Connection Compared with the Double-T Connection

The common connection for two-phase to six-phase transformation is the so-called double-T or double-

Scott connection shown in Fig. 2. While structurally there is a great deal of resemblance between this and the new connection, what little difference there is accounts for the difference in the apparatus economy of the two connections. The maximum apparatus economy which the Scott connection is capable of is 96.6 per cent (using non-interchangeable units and properly interlaced three-phase main windings) as against the 100 per cent apparatus economy of the new connection. Besides

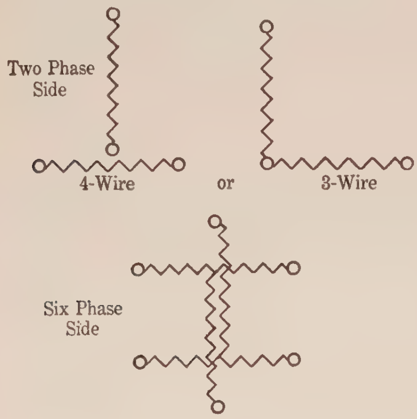

FIG. 2—DOUBLE-T OR DOUBLE-SCOTT CONNECTION

this difference in economy, the new connection is free from the trouble of the interlacing requirement for the two halves of the main winding in the Scott connection. This advantage is more appreciated if it is considered that six-phase circuits are usually of low voltage and high current, and proper interlacing of the two halves of the main is not a simple matter.

It will be observed that the Scott connection can be converted into the new connection by redistributing the two teaser windings around the two main windings in accordance with Fig. 1.

A disadvantage of the new connection in comparison with the Scott connection is that the former is not adaptable for the use of interchangeable units. If a spare is needed, it must be a complete polyphase unit, while in Scott connection a single-phase spare may be sufficient. In this interchangeable scheme, however, the apparatus economy of the Scott connection is at best only 93.8 per cent.

NEW CONNECTION COMPARED WITH THE WOODBRIDGE CONNECTION

The Woodbridge connection is a 100 per cent economy connection shown in Fig. 3. Originally this connection was intended for two-phase to three-phase transformation, but its applicability to two-phase to six-phase transformation is obvious. The Woodbridge connection, although of high economy, is seldom used on account of three limitations; (1) being a 4-wire two-phase connection, it is not adaptable to 3-wire two-phase circuits; (2) the two-phase side is unsuited for taps; and (3) it is as complicated for two-phase to three-phase service as for two-phase to six-phase service, while in the matter of simplicity, adaptability and convenience for two-phase three-phase service the Scott connection is far ahead of any of the other many connections so far invented. The new connection here described is not adaptable at all to three-wire three-phase service.

For six-phase service, the Scott, the Woodbridge and the new connections are of the same order of complexity in the matter of windings, but the latter two do not need the particular interlacing required by the Scott connection. Since taps are or would be placed on the two-phase side, in this service the Woodbridge connection is at a very serious disadvantage.

A point of great theoretical interest in this comparison is that both of the two 100 per cent economy connections are "diametric" in their derived phases, but free and flexible in their original. The Woodbridge connection uses three-phase flux, and is flexible in its three-phase side, its original side, being capable of either diametric or mesh connection. However, on its derived side,—viz., the two-phase side,—the connection

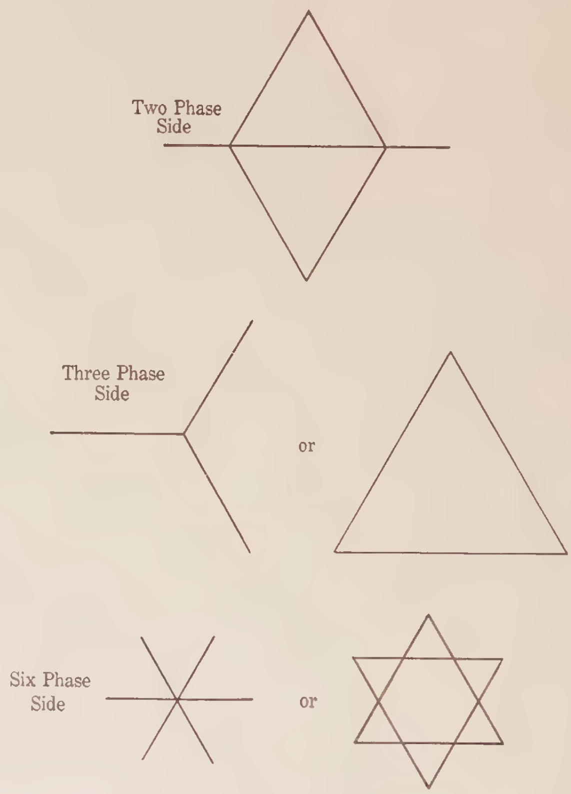

FIG. 3—THE WOODBRIDGE CONNECTION

is entirely limited to four-wire diametric connection. The new connection here described utilizes two-phase flux, and this being its original phase, it is capable of any two-phase connection. However, on its derived side, the three-phase side,—it has to be diametric, that is, six-wire three-phase, and is therefore not adaptable to ordinary three-wire three-phase circuits.

Oil-Filled Terminals for High Voltage Cables

BY EUGENE D. EBY[1]
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***Synopsis.**—Underground cables for transmission of power at 33,000 ft. and above have only recently come into use in America, or received much attention here. In connection with such cables suitable terminals are necessary and present an important problem in high voltage design.*

A marked tendency is noted toward the oil-filling of cable joints; terminal conditions make this procedure both logical and desirable.

Dielectric strength must first be specified, and should exceed that of the cable; flashover should occur without puncture; lightning voltages should be guarded against in the design. Proper d-c. tests are still undetermined for various combinations of solid and liquid dielectrics, and a rigid practise can not yet be established with assurance. At present, high voltage cable lines are intended for a-c. operation, and safety factors should be determined for that kind of service. High voltage d-c. operation may come into practise later, and research in d-c. testing should be pushed.

Standard ratings of terminals are proposed, corresponding to the accepted standard ratings for other high voltage apparatus. Consistency with other terminal insulation, such as apparatus bushings and line insulators, is desirable. Cable insulation may eventually experience similar standardization. The method of rating single-conductor and three-conductor cables should be harmonized, and both based on operating-line voltage.

Four typical designs of high voltage cable terminals are described representing a carefully worked out and effective solution of the problem. These are (a) 37,000-volt three-conductor; (b) 50,000-volt single-conductor; (c) 73,000-volt, single-conductor; and (d) 110,000-volt single-conductor. Flashover tests and time tests, corresponding to breakdown and endurance tests on equivalent cables, are reported to illustrate the ability of the terminals to withstand factory and field tests on the cables, and to show the ample factors of safety under operating conditions. Results of an experimental installation of the 110,000-volt terminals demonstrate the safety of the design, predicted from calculations and confirmed by laboratory tests.

For temporary testing purposes these oil-filled terminals are most convenient and economical, and contribute to the uniformity and reliability of the results in cable testing, which are the factors of greatest importance.

Oil-Filled Terminals for High Voltage Cables

With the introduction of lead-encased cables into the field of high voltage power transmission, there has arisen the necessity of providing, at the ends of these cable lines, suitable terminals or end-bells, capable of maintaining safe connection between the cable and the apparatus or the overhead line with which it is to operate. Three-conductor 33,000-volt cables have been used in this country for only a few years, and the number of such installations is still small. Operation of single conductor cable lines at higher voltages is still more recent. Interest in high voltage power transmission over cable lines has been rapidly increasing because of the large blocks of power which it is necessary to deliver through congested urban sections, and which cannot be handled on overhead lines. At present there is active interest in cable for 132,000-volt operation and a reasonable prospect of attaining this rating in the not-far-distant future. This rapid increase in cable voltage has led to an intensive effort in the development of the necessary joints and terminals for these higher voltage cables. It is the purpose of this paper to present some of the results of this work as related to the problem of terminals.

Tendency Toward Oil Filling

There is evident in the development of high-tension cable joints a definite tendency toward oil filling, *i. e.*, complete filling of the enclosing shell with a fluid oil under sufficient pressure from auxiliary reservoirs to eliminate all voids or pockets within the joint. The use of hard compounds is accompanied with certain well-known and serious disadvantages, among them being the shrinkage upon cooling which leaves unfilled cavities, separation from the surfaces of the insulating materials thus inviting local breakdown, and incomplete sealing of the joint against entrance of moisture through holes in the shell and the lead wipes. These disadvantages are effectively corrected by the use of a fluid filler under pressure.

The tendency toward the oil-filling of cable joints has already received expression by the substitution of softer compounds as fillers in place of the harder compounds commonly used with the lower voltage joints. Of the soft compounds petrolatum is the most common, while in one or two prominent cases a mixture of transil oil and petrolatum has been employed. Auxiliary pressure reservoirs of several types have been advocated and used to maintain complete filling of the joints. The use of these softer fillers has been fully justified by the results obtained, and these point the way to the oil-filled joint as a logical and promising solution of splicing in high tension cable lines.

Terminal Conditions

From similar considerations the oil-filled terminal is the logical solution of the problem of insulating the ends of high tension cables. In two prominent particulars the terminal offers a simpler problem than the joint, in that space limitations are largely removed, and the bared conductor does not have to be enclosed within grounded metal. On the other hand, the terminal presents difficulties not met with in joint design, since it combines the joint problem of insulating the cable end from the sheath by solid and liquid dielectrics, with the further problem of insulating it at the

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same time from the sheath through the air. There is also the greater temperature variation, and complete exposure to the elements. In addition to these physical differences, the location of a terminal at the junction point between underground cable and overhead line may at times impose far greater potential strains upon its insulation than most of the cable system is ever called upon to withstand. The cable terminal in general, therefore, is subject not only to those potential stresses originating or developing within the cable system, but also to those stresses occurring in the overhead system as well, including lightning. This latter source of over-voltage stress is usually far more destructive to solid insulations than to liquids. The use of oil in a cable terminal offers the best known means of dealing with the lightning problem, at the same time contributing very effectively to the quality of the cable near the terminal by serving as an oil reservoir.

Dielectric Tests

The dielectric strength is the first feature of the design to be determined. Obviously the terminal must be able to withstand all tests applied to the cable after installation. This it might do but still be weaker than the cable. Properly, it should be *stronger* than the cable so that it will not fail at any voltage, either momentary or sustained, which the cable can withstand. By failure is meant internal breakdown. The internal strength should be greater than external flashover, the value of which should be consistent with the flashover of bushings on connected apparatus and insulators on connected lines. The desirability of flashover without puncture in the case of bushings and insulators is well established, and the same should be true of cable terminals. The terminal, therefore, should be able to withstand both the short breakdown tests and the longer time tests, it should flashover externally without internal failure at normal frequency, and it should be as nearly lightning proof as possible.

In the foregoing paragraph, alternating voltages have been in mind. Of course, where d-c. testing is employed the terminals must be able to withstand the applied d-c. voltages. Whether this means a greater strength than for a-c. testing will depend largely upon the kind of insulation and the ratio of d-c. to a-c. voltage. The proposed ratio of 2.4 is probably not far from correct for cable paper; for oil a smaller ratio exists, nearer 1.5; and for a combination of oil and paper an intermediate ratio would probably apply, expected to vary with the proportions of these materials. At present, data on the strength of various materials under high direct voltages are too meager to draw definite conclusions or establish a rigid practise. It should be remembered, however, that the terminals and cable are to operate with alternating current, and it is of first importance that they withstand a-c. potentials successfully. The difficulties of applying a-c. tests to long lines of high capacitance will encourage the use of d-c. testing equipment; and some cable lines installed at first for a-c. operation may even experience later on a conversion to d-c. operation. Research in d-c. testing must, therefore, be pushed vigorously, in order that only proper d-c. tests shall be employed. It is not unlikely that both kinds of tests will become a part of the designer's check upon his product.

Standard Ratings

In order that both manufacturer and consumer may benefit by standardization of parts and designs, standard ratings should be adopted and designs developed accordingly. It seems logical that the standard voltage ratings for high-tension apparatus should apply to cable terminals as well. This would harmonize terminal design with that of bushings, insulators, switches, metering transformers and lightning arresters. Standard ratings, as shown in the following tabulation, are already in general accepted use for these devices.

15,000	88,000
25,000	110,000
37,000	132,000
50,000	154,000
73,000	220,000

These ratings, when applied to cable terminals, should represent the practise for both *Y* and delta circuits, grounded and ungrounded, except as modified for other apparatus using terminal insulators. The cable should not be equipped with terminals of lower flashover voltage than that of the bushings of transformers, circuit breakers, and lightning arresters connected thereto.

Intermediate ratings of cable may be found necessary for economic reasons. This will not prevent the use of standard terminals, however, which is highly desirable so that their line-to-ground flashover strength shall not be inferior to other apparatus on the system. It is already generally recognized that the insulation of apparatus located at different points on a high tension system should have a uniformly high value, even though some of the apparatus is located on a part of the system normally operating at lower voltage than another part. Cable insulation may eventually experience this same standardization.

This proposed standardization of voltage ratings of terminals for high-tension cables emphasizes the desirability of a uniform practise in applying voltage ratings to the cables themselves. Three-conductor cables are rated in terms of line-to-line voltage and their tests determined by this rating. In the case of single-conductor cables, however, it has been the practise to determine their test voltage on the basis of their working voltage between conductor and sheath. This has often resulted in the working voltage from conductor to sheath being used as an expression of the operating voltage, whereas in the case of all other apparatus the operating voltage is understood to be the voltage from line to line. It would appear rather inconsistent to rate single conductor terminals in terms of the working voltage of

the cables, as this would give the terminal an entirely different rating from the other apparatus to which it will be connected. For example, a single conductor cable for a 50,000-volt system, although its working voltage is 28,900 volts, should have a terminal whose rating is 50,000 volts. Furthermore, if the cable and its terminals are to have their voltage ratings determined on the same basis, both would properly be assigned a rating of 50,000 volts.

Typical Designs

In light of the foregoing considerations, a careful study of the high-voltage cable terminal problem was made, which resulted in certain definite design features, including oil filling. To illustrate the principal features of these oil-filled terminals, four sizes will be described; (*a*) 37,000-volt, three-conductor, corresponding to the highest rated satisfactory three-conductor cable yet produced, viz., 33,000 volts; (*b*) 50,000-volt single-conductor, applicable to the lowest rated single cables above the present three-conductor range; (*c*) 73,000-volt, single-conductor, corresponding to the highest rated single cable in practical operation in this country; and (*d*) 110,000-volt, single-conductor, as now being used in the highest voltage experimental cable installation thus far undertaken. Terminals of this last rating were used also in the elaborate series of tests conducted by the Electrical Testing Laboratories of New York at the Pittsfield Works of the General Electric Company during the summer of 1924, when several manufacturers contributed samples of their best efforts toward 132,000-volt cable.

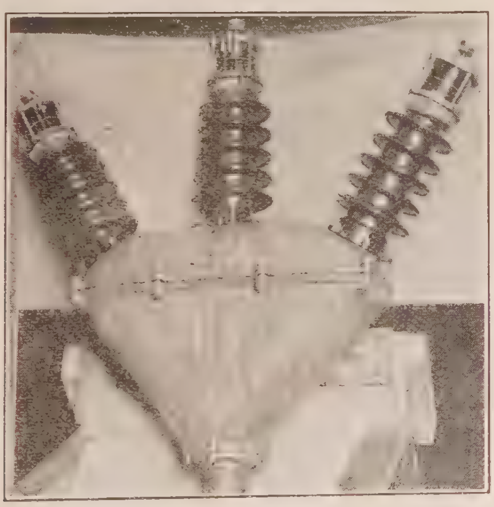

Fig. 1—37,000 Volt, Three-Conductor, Oil-Filled Terminal for Lead-Covered Cable

37,000-volt three-conductor terminal. This design is illustrated in Fig. 1. The three insulators are in the same plane, an arrangement which makes the tank very much larger than a triangular arrangement, and the spread of the insulators twice as great; but it lends itself readily to wall or pole mounting. Sufficient space in the tank has been allowed for transposition of conductors for phasing, without intermediate link connectors. No side opening in the tank is necessary, as the insulators and cover are removable. The insulators are of wet-process porcelain formed in one piece, with smoothly ground ends, against which bakelized cork gaskets are compressed by means of the metal clamping rings cemented around the ends of the porcelain.

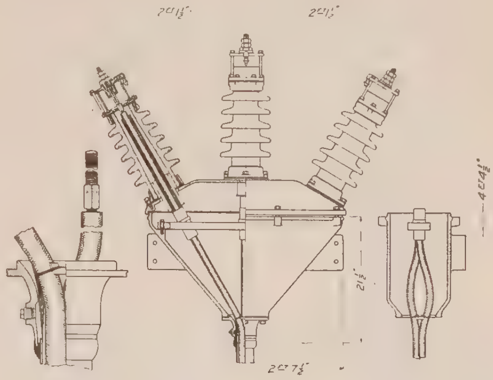

Fig. 2—Drawing Showing Construction of 37,000-Volt, Three-Conductor Oil-Filled Terminal for Lead-Covered Cable

The glass cylinder mounted above each insulator serves as a sight glass registering the level of the oil with which the terminal is filled. An auxiliary reservoir should be provided in connection with a tank of this size, to care for the expansion of the large volume of oil,—in this case about 22 gallons. The lower end of the iron tank is flanged and bolted to the brass wiping sleeve. The joints here and from tank to cover, as well as at the ends of the porcelain insulators and glass gages, are made oil-tight with treated cork gaskets. Filling and draining is accomplished through a pipe connection to the wiping sleeve.

The internal construction is shown in Fig. 2. The cable sheath terminates just within the wiping sleeve. A thin copper band slipped under the end of the lead protects the paper from sharp edges and damage in soldering. The belt insulation is removed in steps, and the three conductors separated and spaced by a porcelain block. A reenforcement of insulating tape is built up around the outside of the three conductors to give predetermined shape and dimensions, so chosen as to secure a safe distribution of both radial and lateral stresses. Upon the lower portion of this reenforcement is wound an overlay of metal tape, soldered at the lower end to the cable sheath. The upper end of this metal overlay approaches close to the inner surface of the wiping sleeve, which then recedes from the reenforcement and the conductor insulation to meet the lower flange of the tank. The shape of these metal surfaces vitally influences the potential stresses radially and laterally, and largely controls the circumferential stress around the conductor insulation, which seems to be a large factor in so-called *crotch failures*.

Above the reenforcement, the conductors pass in gentle curves to porcelain tubes mounted in a treated wood support, and thence in straight lines to the terminal studs soldered to their bared upper ends. Fairly close fitting paper tubes preserve the concentric alignment of the conductors within the grounded metal shields in the cover. These shields present a smooth, uniform and definite surface to the electric field from the conductors, and also serve to improve the potential distribution on the external surface of the porcelain shells.

The terminal stud at the end of each conductor is locked in place by a double-threaded nut in the recessed depression of the top washer. A terminal cap engages with the stud and seals the top against moisture by an enclosed cork gasket. External connection is made through attachment to the threaded stud extending

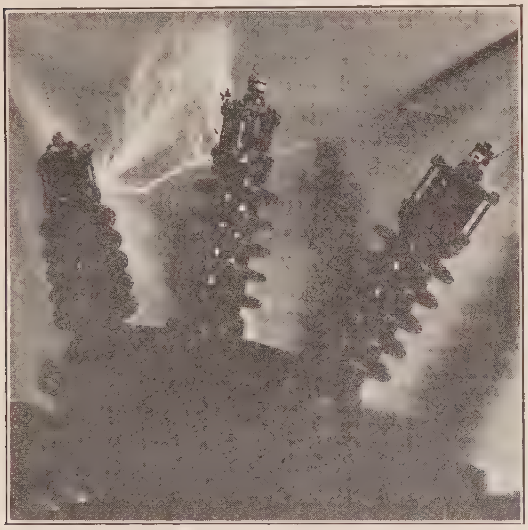

Fig. 3—Flashover Test at 170,000 Volts from Cap-to-Cap on 37,000-Volts, Three-Conductor Oil-Filled Terminal for Lead-Covered Cable

from the top of the terminal cap. A drain cock in the top washer above each gage glass permits the escape of air during filling of the terminal with oil.

Samples of this terminal have been tested with three-phase potential to flashover at 170,000 volts, from cap to cap, as shown in Fig. 3. The flashover voltage from cap to case is about 150,000 volts. Time tests have been made at 76,000 volts for seven hours, followed by 100,000 volts for four hours. Subsequent examination failed to disclose any signs of deterioration.

While such terminals for three-conductor cables are perfectly practicable from the standpoint of design, they have some disadvantages in installation, cost, and maintenance, that encourage the use of single-conductor terminals on short single cables spliced to the three-conductor cable, a short distance from the end of the line. This practise is likely to displace the former for sound technical as well as physical reasons. With a length of single cable at the end of the line, extra insulation may be provided against the higher stresses in a connected overhead line, or, due to proximity to reflection points in connected apparatus. Single terminals which can be mounted directly underneath overhead lines of greater spacing than the three-conductor terminal would have, are much smaller and lighter in weight and hence easier to handle, and require much less oil for filling with consequently less expansion capacity in the oil reservoir. The glass gage at the top of the single type of terminal is sufficient for the expansion of the oil in the terminal itself. Single-conductor terminals for higher voltages are described in the following paragraphs. Designs for the lower voltages where

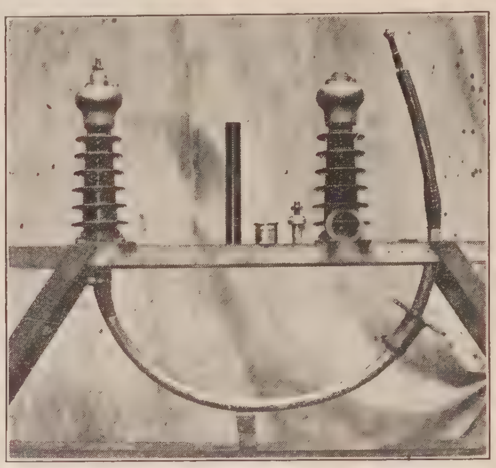

Fig. 4—50,000-Volt Single-Conductor Oil-Filled Cable Terminals with Test Piece of 20/32 In. Paper Insulated Lead-Covered Cable. Right Hand Terminal Dismantled to Show Construction

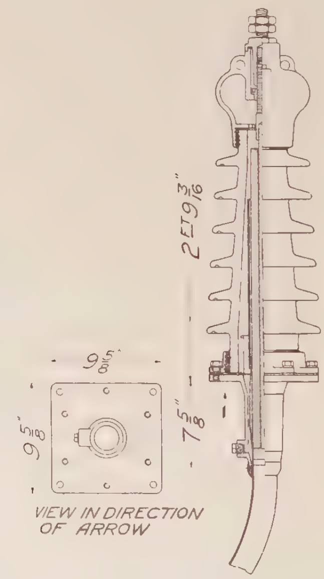

Fig. 5—Drawing Showing Construction of 50,000 Volt Single-Conductor Oil-Filled Terminal for Lead-Covered Cable

three-conductor cables are used, as at 22,000 volts and 33,000 volts, have been worked out along the same lines.

50,000-Volt Single Terminal

This design is illustrated in Fig. 4. In this case the wiping sleeve and support are in one piece, the latter taking the form of a square flange for bolting to horizontal brackets. The one-piece porcelain shell is cemented into the clamping ring at its lower end, and into the recessed cap at its upper end, with cork gaskets in the joints. The cap shown in the illustrations was designed for petrolatum-filled terminals; for oil-filled terminals a glass gage would be used to give a constantly visible indication of the oil level. The connection details at the top are similar to those described for the 37-kv. terminal.

The internal construction is shown in Fig. 5. The lead sheath terminates, as before, just within the wiping sleeve, and the copper band is inserted under the edge of the lead. A reenforcement of insulating tape is applied directly upon the cable insulation, and the lower end of this reenforcement is overlaid with a metal tape up to its greatest diameter. The reenforcement projects above the support flanges and within the grounded metal shield, with dimensions so chosen as to keep the radial and lateral stresses within safe values. A paper cylinder surrounding the conductor insulation, and spaced from it by means of narrow strips of press-board keeps the conductor straight and concentric within the ground shield, and divides the oil space into cylindrical ducts, thus increasing the insulating value of the oil, and directing its circulation.

Fig. 6—Flashover Test at 190,000 Volts on a 50,000-Volt Single-Conductor Oil-Filled Terminal for Lead-Covered Cable

Samples of this terminal assembled with 500,000 cir. mils 20/32 in. paper cable[1] have received repeated flashover tests at an average of 190,000 volts, as shown in Fig. 6, and have subsequently withstood, in consecutive order, the combination of all the several cable tests for 40,000-volt cable taken from the proposed Edison specifications, as follows:

114,000 volt for 5 min. (breakdown test)
71,000 volt for 15 min. (full reel test)
57,000 volt for 8 hours (high voltage time test)

No disturbance of any kind developed during these tests, and no deterioration could be observed upon later examination.

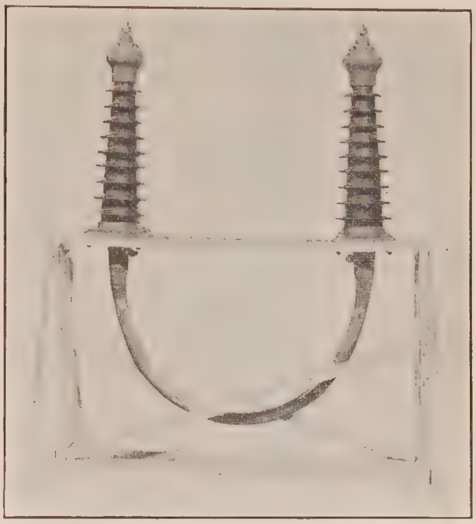

Fig. 7—Two 73,000-Volt Single-Conductor Oil-Filled Terminals for Lead-Covered Cable, Assembled with Test Piece of 66,000 Volt, 30/32 In. Paper Insulated Cable

73,000-Volt Single Terminal

In Fig. 7 there is shown the terminal developed for use with 66,000-volt cable. In external appearance and construction it closely resembles the 50,000-volt terminal just described. Internally, the only prominent difference is in the insulating of the metal ground shield by embedding its upper end in varnished cambric supported directly upon the paper cylinder. Perforations through the flange of the ground shield permit downward flow of the circulating oil in the duct outside of the cylinder. These details and the general construction are illustrated in Fig. 8.

A typical flashover test on this terminal at 290,000 volts is shown in Fig. 9. Time tests on sample terminals have been made at 200,000 volts for several hours. These terminals have also been used with great satisfaction in making time tests on samples of 30/32 in.

1. Cable of this size and insulation is being installed at Columbus, O., for operation at 40,000 volt, three-phase.

paper cables at 200,000 volts and in one instance, a test of 225,000 volts for 36 hours was made on such a cable with no terminal trouble.

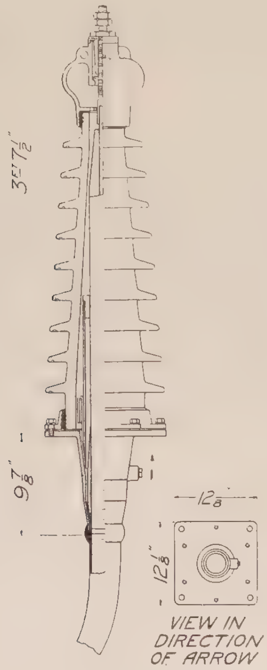

Fig. 8—Drawing Showing Construction of a 73,000-Volt Single-Conductor Oil-Filled Terminal for Lead-Covered Cable

110,000-Volt Single Terminal

The terminals shown in Figs. 10, 11 and 12 were developed first for testing of cables having 30/32

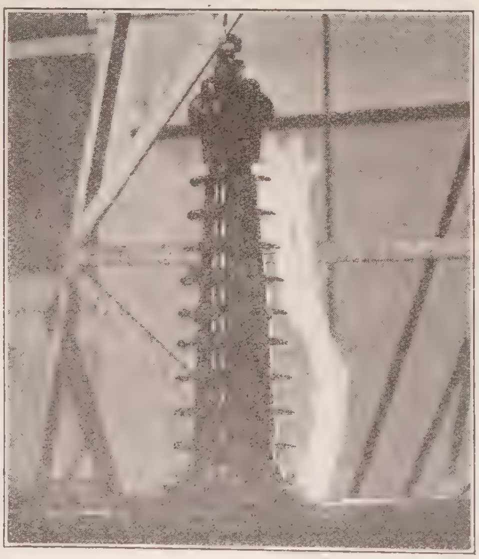

Fig. 9—Flashover Test at 290,000 Volts on a 73,000 Volt Single-Conductor Oil-Filled Terminal for Lead-Covered Cable

in. paper insulation, to determine how near an approach had been made to a safe and reliable 132,000-volt cable. For economy and convenience in assembly, the wiping sleeve is separate from the horn-shaped support casting, with a cork gasket between bolted flanges to form an oil-tight joint. A re-enforcement of insulating tape encircles the cable insulation from the termination of the lead sheath to a

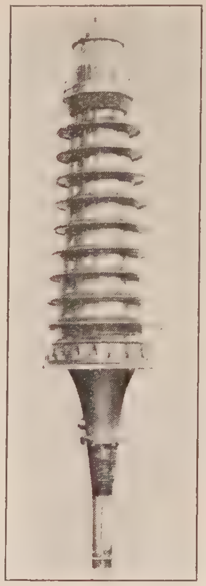

Fig. 10—110,000-Volt Single-Conductor Oil-Filled Terminal for Lead-Covered Cable

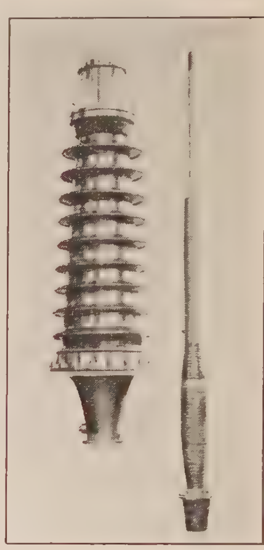

Fig. 11—110,000-Volt Single-Conductor Oil-Filled Terminal for Lead-Covered Cable, Showing Terminal Removed from Cable, Exposing Re-enforcement of Cable Insulation

point opposite the top of the ground shield. Radial and lateral stresses are controlled as before by this re-enforcement, together with the configuration of the enclosing metal. A bare ground shield is possible by

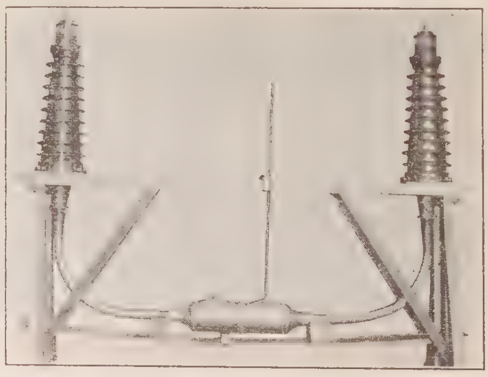

Fig. 12—Two 110,000-Volt Single-Conductor Oil-Filled Terminals for Lead-Covered Cable, Assembled with Two Pieces of 30/32 In. Paper-Insulated Cable Spliced with an Oil-Filled Joint

reason of its diameter, and two paper cylinders break up the oil space into vertical ducts. In addition to the ground-shield, a terminal-shield is provided inside the upper end of the porcelain shell to improve the potential distribution along the outside surface of the porcelain.

The porcelain shell and its two clamping rings, and the glass oil-gage and the two adjacent castings are borrowed without change from the standard interchangeable oil-filled bushing for transformers, oil circuit breakers, and lightning arresters, and illustrate again the value, and convenience of standardized

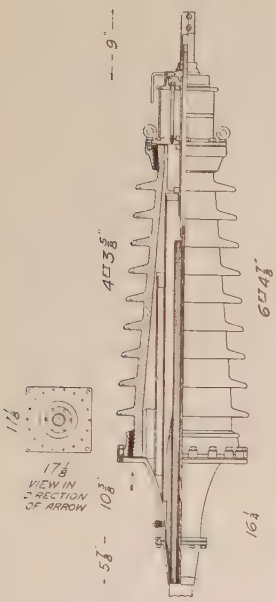

Fig. 13—Drawing Showing Construction of a 110,000-Volt Single-Conductor Oil-Filled Terminal for Lead-Covered Cable

Fig. 14—Flashover Test at 400,000-Volt on a 110,000-Volt Single-Conductor Oil-Filled Terminal for Lead-Covered Cable

material. The details are shown in Fig. 13. The construction is such that, with the exception of the top connector and the wiping sleeve, this terminal may be assembled complete before installing over the prepared end of the cable. This is of great advantage in a terminal of this size and weight, which must be handled with a hoisting tackle of some kind. During installation the long stud, into which the end of the cable is soldered, is passed through the tube in the top of the terminal and secured at the proper elevation by a lock nut above the cover casting. The wiping sleeve is then raised into position, bolted to the support casting, and wiped to the lead sheath.

In the tests on the proposed 132-kv. cable, for which this terminal was first developed, it successfully withstood the breakdown tests up to its flashover voltage of 350,000 volts. These breakdown tests were made, as usual, by starting at some predetermined voltage, and increasing in 10 per cent steps at short intervals. Momentary flashover voltages of 400,000 volts, as shown on Fig. 14, have since been measured on these same terminals, when raising the voltage steadily up to the flashover point. Time tests of six hours at 275,000, and eight hours at 240,000 volts were obtained on some samples of cable, the terminals functioning with complete satisfaction. With sufficiently good cable, it is probable that time tests as high as 300,000 volts for eight hours could be made without trouble developing in these terminals.

It is of very real practical interest, also, that an experimental or trial installation of similar cable equipped with these terminals is receiving a service test on the 110,000-volt system of the Adirondack Power and Light Company, at Albany, N. Y. Fig. 15 shows the installation. This piece of cable is lying exposed on the ground with the ends extending into the terminals, which are mounted on a frame work several feet high. An auxiliary reservoir of oil maintains the oil in the terminals at the proper level, and supplies whatever absorption into the cable there may be. No current is carried by this cable, which fact, coupled with its exposure above ground, imposes a much more severe temperature variation than would be the case with a loaded cable buried in the ground. The test has been running now for four months (to Feb. 1, 1925), and the terminals have given no trouble whatever.

Terminals for Testing Purposes

It may not be inappropriate to say a word about the use of such terminals, as are here described, for temporary or testing purposes. While at low voltages it is usually sufficient to immerse the ends of the cable in

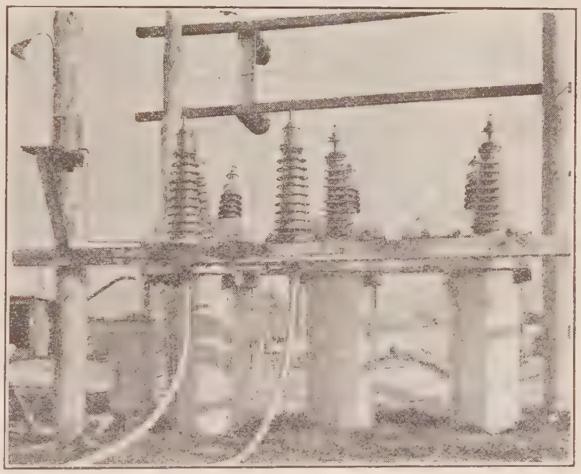

Fig. 15—Experimental 110,000 Volts Cable Undergoing Field Test at North Albany Station of Adirondack Power and Light Corporation, Equipped with 110,000 Volts Single-Conductor Oil-Filled Terminals

oil or compound, either in a tank or by means of cones of metal or paper surrounding the ends of the cable, yet at higher voltages, such as more than 200,000 volts, such temporary methods often become both inconvenient and unsatisfactory in results. The oil-filled type of porcelain terminal, as described above, lends itself most admirably to testing purposes,[2] as well as to permanent

2. See also paper on "Testing High-Tension Impregnated Paper-Insulated, Lead-Covered Cable" by Everett S. Lee, presented at the Midwinter Convention A. I. E. E., New York, Feb. 9-12, 1925.

service installations. The preparation of the cable ends for assembly with the terminal is a simple and rapid process, the terminal parts are easily and accurately adjusted to the cable, the oil filling can be done without delay, and the testing can proceed almost as soon as the filling is completed. With equal facility, the oil can be drained, the terminal removed, and a new piece of cable prepared for test with the same set of terminals. Not only does this method speed up the work, but it makes necessary only a small amount of equipment, avoids the use of large tanks of oil, and saves the loss of much temporary material wasted in some methods of testing. Of even far greater importance are the uniformity and reliability of results obtained, which factors are well nigh indispensible to the value of the test data on the cables themselves.

CARRIER CURRENT TRANSMISSION FOR UNDERGROUND COMMUNICATION

A report has recently been issued by J. J. Jakosky and D. H. Zellers, both of the Bureau of Mines, on the effect of Metallic Conductors on Underground Communication. This report contains (1) a discussion of the chief factors affecting carrier-current transmission with particular reference in application to underground communication for mines; (2) a description of typical underground circuits used for power and lighting; and (3) description of results obtained in carrier-current experiments in coal mines near Pittsburgh, and conclusions as to power requirements and limitations for mine use.

Factors Governing Carrier-Current Transmission

In designing apparatus for carrier-current telephony for underground purposes, the general behavior and characteristics of mine circuits as high-frequency channels must be considered. A typical mine power system usually consists of combined aerial and cable circuits; on the surface the aerial lines are, as a rule, well insulated and with effective spacing between wires; underground, the cables may be run in conduit, twisted pair, or duplex, depending upon type of service, or spaced six or more inches, depending on the prevailing conditions. The leakage of underground lines is usually high as compared to surface lines, on account of moisture and the fact that wires are run within a few inches of, or often touching, the wet mine walls, or are incased in metal conduits.

In practically all direct-current mine installations, large copper conductors are used, in order to decrease the voltage drop in the distributing system. Such large low-resistance conductors, with an absence of transformers, etc., provide almost ideal conditions for carrier-current operation. The distances to be worked, usually not greater than 5000 to 10,000 feet, allow under favorable conditions comparatively, low powers to be used for transmitting and very simple equipment for receiving.

Operating carrier-current over alternating-current mine systems offers considerably greater difficulties. The alternating-current systems, as a rule, use higher voltages and smaller conductors from the power house and surface lines into the mine; and transformers or synchronous converters are used for obtaining proper voltages at distribution points. When a carrier-current set operates over conductors containing transformers and equipment of similar electric characteristics, suitable by-pass and shunt condensers should be used, to carry the high-frequency current past the transformer, etc.

General Conclusions

1. A carrier-current apparatus to be of practical mining use must be so designed that it will operate efficiently over conductors of widely varying electrical characteristics.

2. Short-wave carrier-current apparatus is too critical in adjustment and operation for practical mine use. Every change in the metallic circuit, such as breaks in the line, grounds, etc., necessitates readjustment of the apparatus if efficient operation is to be obtained over distances of a few thousand feet or more.

3. The long-wave apparatus, while not as critical in operation as the short-wave, still requires more adjusting in cases of changes in the circuit than is now believed practical for underground mine use, especially in cases of disaster or when emergency communication must be established.

4. Studies and investigations of different mine accidents after explosions and fires show that overhead wiring, such as trolley wires, and power, lighting, and telephone circuits, are usually broken or destroyed to an extent to render unreliable their use in cases of diaster. In times of emergency and during mine-rescue operations, whatever means of communication is employed must be not only reliable but portable, simple, and quick to operate. In such cases, the use of an apparatus that requires tuning or adjusting for satisfactory operation over broken conductors whose electrical constants have been changed by such disasters might be of doubtful benefit to the rescue crew, although it might be of some value to the entombed men who, by their enforced waiting and idleness, can tune or adjust a set—if they have one. More than the simplest type of adjustment, however, is out of the question because of the lack of training of the average miner, absence of light, and adverse physiological and psychological conditions.

5. Practically the only metallic conductors in mines that are not destroyed at one or more points by a disaster are buried conductors (power and lighting circuits in underground circuit), water and compressed air piping, and track returns. Such conduits are poor carriers for high-frequency currents. The low-frequency T. P. S. and voice apparatus carries much more efficiently over such conductors.

Eight Years Experience with Protective Reactors

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and

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Synopsis:—*In 1914 the authors presented before the Institute two analytical papers on Protective Reactors. During 1917, 1918 and 1919 three large power stations embodying what seemed to be the best system of bus and feeder reactors were placed in operation. The present paper gives brief accounts of sixteen accidents on the buses or feeders of these power stations. In each case the reactors effectually kept the power concentration within such limits that the damage was localized, and no troubles were experienced from mechanical displacement of conductors and insulators elsewhere.*

In concluding, the authors state that their experience with reactors leads them to believe that short circuits in the largest power stations can be so controlled by a properly designed system of reactors that their destructive effects will be confined to the immediate vicinity of the arc, and that it will be possible so to tie together power stations and power systems of any magnitude that a short circuit will be of merely local significance and will not jeopardize the service of other parts of the system.

IN February, 1914, the authors presented before the A. I. E. E. a paper entitled "Protective Reactances in Large Power Stations." In October of the same year they presented a second paper entitled "Protective Reactances for Feeder Circuits of Large City Power Systems." These studies were made for the purpose of determining the best reactor system for two large steam power stations on which preliminary design studies were then being made.

In the second paper it was shown by a series of curves[2] (Curve Sheet No. 6) that after a certain number of generators are connected to a ring bus, with reactors between adjacent generators, the number may then be increased to infinity without appreciably increasing the amount of current flowing into a short circuit on the bus. Based on the reactance values of generators and bus bar reactors which at that time seemed most desirable and which experience has changed but little, the following figures derived from the curves[2] will be of interest:

1. After three generators are installed, the number of generators can be increased to infinity without increasing by more than 50 per cent the amount of current that can flow into a short circuit on the bus.
2. With an infinite number of generators, the maximum amount of current that can flow into a short circuit on the bus is about 3½ times the short-circuit current than can be obtained from a single generator.

The system of connections finally adopted was a ring bus with five per cent bus reactors between adjacent units, based on turbo-generator units of the order of 25,000 kw. to 30,000 kw. at 0.8 power-factor, and a radial system of feeders with three per cent feeder reactors, based on feeders of 6000 kv-a. to 7500 kv-a. at 11 kv. to 13.2 kv. The bus reactors are shunted by oil circuit breakers which are so controlled that when one or more generators are disconnected from the bus, the corresponding set of adjacent bus reactors is automatically shunted, thereby preventing more than one set of bus reactors from being in circuit between any two adjacent running generators. This scheme of connections with eight generators in service is shown diagrammatically in Fig. 1. In Fig. 2 and Fig. 3 are shown the connections when but one-half the generators are in service. This system of connections limits the flow of current into a short circuit on a generator or on any section of the bus after a lapse of 0.1 sec. to a value of approximately 750,000 kv-a. The flow of current into a feeder short circuit is limited to a value of approximately 250,000 kv-a.

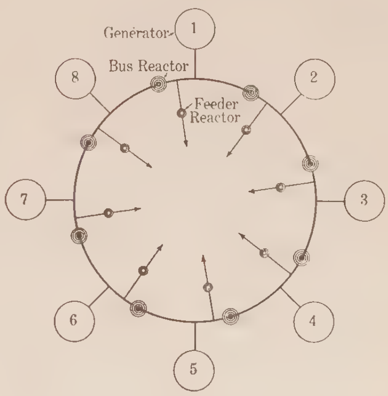

FIG. 1—SCHEME OF CONNECTIONS—ALL GENERATORS IN SERVICE

It is the object of this paper to recount some of the actual operating experiences in power stations where this reactor system has been in service for several years.

In 1916 construction work was started on the Windsor (West Virginia) Power Station of the American Gas & Electric Company and the West Penn Power Company. This station was placed in operation during 1917 with one 30,000-kv-a. turbo-generator. The following table shows its growth:

Year	Units Started Operation	Total kv-a. Capacity
1917	One—30,000-kv-a.	30,000-kv-a.
1918	One—30,000-kv-a.	60,000-kv-a.
1919	Two—33,333-kv-a.	126,666-kv-a.
1923	Two—33,333-kv-a.	193,333-kv-a.

During the years that this station has been in operation, there have been several short circuits of sufficient

1. All of Sargent and Lundy, Inc., Chicago.
2. These curves give current values which correspond approximately to the 0.1 sec. values on the latest decrement curves.

Presented at the Spring Convention of the A. I. E. E., St. Louis, Mo., April 13-17, 1925.

severity to test the effectiveness of this scheme of reactors, and to demonstrate its ability to keep down the flow of short circuit current to a value well within the interrupting capacity of moderately heavy duty oil circuit breakers and to localize the damage to the immediate vicinity of the arc. Below are given brief narratives of several of these short circuits:

1. On August 15, 1919, with three generators running, an employe accidentally placed a ladder against a high tension lead

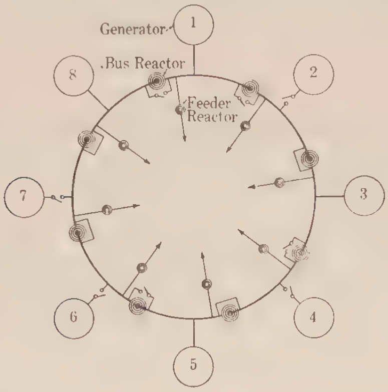

Fig. 2—Scheme of Connections—Generators Nos. 2, 4, 6 and 7 Shut Down

in the 66-kv. switchyard. The circuit breaker on the low-tension side of the transformer bank, feeding these bus bars, tripped and cleared the trouble. A few minutes later the low-tension breaker was again closed. Immediately a quantity of oil squirted out of one of the transformers between the tank and cover. The 11-kv. circuit breaker again tripped out and cleared the circuit. An examination of the damaged transformer, which was one unit of a 20,000-kv-a. bank, showed that the lower turns of the 11-kv. coils were badly damaged both by burning and by the destructive forces of heavy currents. The high-tension coils, although un-

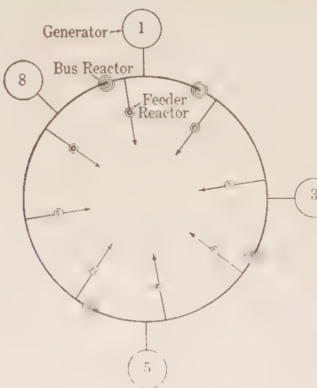

Fig. 3—Simplified Diagram of Connections—Generators Nos. 2, 4, 6 and 7 Shut Down

damaged, were somewhat displaced. The total damage was confined to the one transformer.

2. On May 17, 1922, with four generators running, one of five 3-conductor 500,000-cir. mils 11-kv. cables, feeding a 30,000-kv-a., 132-kv. transformer bank, failed under emergency overload, taking with it several of the adjacent cables. The 11-kv. circuit breaker cleared the trouble from the bus. The following morning a cable on a duplicate transformer bank of the same capacity and voltage failed in a similar manner. In this case also the 11-kv. oil circuit breaker cleared the trouble from the bus bars. These cables were connected directly to the 11-kv. bus bars without series reactors. In neither case did the damage extend beyond the cables and their enclosing conduits.

3. On September 1, 1922, lightning broke down a bushing on one of the 66-kv. oil circuit breakers, causing failure to ground. The overload relay on the 11-kv. side operated properly, but the tripping relay on the 11-kv. oil circuit breaker was out of adjustment and failed to operate. Four generators were connected to the bus at the time, and the flow of current was sufficient to burn out the windings of two transformers of a 20,000-kv-a. bank feeding the 66-kv. bus. The pressure inside of the tanks was so great that the manhole covers were blown off in quick succession, and each transformer sent up a column of flaming oil higher than the stacks of the power-station building. It was several minutes before the switchboard operators discovered the location of the trouble and cleared the transformer bank from the bus, and some time before the oil fire in and around the transformers could be extinguished. Here again, the damage was limited to the two transformers and the area over which the flaming oil had spread.

4. On November 13, 1923, there occurred the most serious electrical trouble which had developed since the station was placed in operation. With all six generators and a seventh duplicate machine operating as a synchronous condenser,—a total of 223,333-kv-a., connected to the bus,—an arc was started by the breakdown of an insulator. The subsequent arcs and flames established a short circuit between the three phases of the main 11-kv. bus. More than a minute elapsed before the switchboard operators located the trouble and killed the power-station bus. A subsequent examination showed that the damage was confined entirely to the short section of bus across which the arc had played. A lighting fixture on the ceiling of the room directly above the arcing bus was not damaged; neither was the reserve bus structure which was separated from the main structure by an aisle space of eight feet. The circuits were, accordingly, transferred to the reserve bus and service was resumed within 48 min.

The West End Power Station of the Union Gas & Electric Company of Cincinnati was placed in operation in 1918, with two 30,000-kw. (31,250-kv-a.) turbo-generator units. In 1920, a third unit, and in 1921, a fourth unit of the same capacity were placed in service making a total present capacity of 120,000 kw. (125,000 kv.a).

All faults on West End Power Station have occurred on the feeders beyond the feeder reactors. Thus, the maximum fault kv-a. has been limited, in all cases, by the feeder reactors which are rated at 0.76 ohm on a basis of 13.2 kv. (three per cent on 300-amperes). Three of the most severe faults are listed below.

1. On July 18, 1921, at 11:42 a. m., a three-phase short circuit developed in a 400,000-cir. mil cable approximately 1½ miles from West End Power Station. At the time, there were two generators running with a total load of 45,000 kw., and two bus reactors in service. The feeder-oil circuit breaker opened to clear the fault without signs of any great disturbance on the rest of the system.

2. On December 15, 1923, a short circuit developed in a 400,000-cir. mil cable approximately ½ mile from West End Power Station. There were three generators running at the time and three bus reactors were in service. The fault current was 6000 amperes in each phase, and was broken by the opening of the feeder-oil circuit breaker. However, there was a sufficient force developed between two of one set of feeder reactors to pull them together with a resultant breaking of the concrete side slabs. These reactors were spaced horizontally one foot apart and were not fastened to the floor. The voltage on the directly affected section of bus was maintained at 70 per

cent of normal, and the rest of the system did not suffer any serious disturbance.

3. The most severe fault that the system has suffered occurred on October 31, 1924, at 9:57 a. m. This was a three-phase short circuit on two adjacent 400,000-cir. mil cables at a point where they changed from underground cables to overhead open lines. At the time there were four generators running and four bus reactors were in service. The two cables were connected to different sections of the bus, so that two of the generators were connected directly to the faulty cables without interposing bus reactors. The fault current was 4300 amperes per phase in each cable (8600 amperes from the system). The bus voltage dropped to 77.5 per cent of normal. One hurling pump motor which was connected to the same section of bus as one of the faulty cables, was tripped out by an undervoltage relay. No other auxiliary motors were affected. The relays operated correctly to open the oil circuit breakers on the two faulty cables.

In 1925, Miami Fort Power Station, with an initial installation of two 38,000-kw. (44,705-kv-a.) turbo-generators will go into service about twenty miles west of West End Power Station. This station will have the same system of bus and feeder reactors that has worked out so successfully at West End Power Station.

In the winter of 1919-1920 the Northeast Power Station of the Kansas City (Missouri) Power & Light Company was placed in operation with two 20,000-kw. (25,000-kv-a.) turbo-generator units. The following table shows the growth by years of this station:

1919—One 20,000-kw. 25,000-kv-a.
1920—Two 20,000-kw. 25,000-kv-a.
1922—One 30,000-kw. 37,500-kv-a.
1925—One 30,000-kw. 37,500-kv-a.

Total present capacity 120,000 kw. (150,000-kv-a.)

The Northeast Power Station is located northeast of the main business district of Kansas City on the low bottom lands which border the Missouri River. As there was initially no practical way of carrying underground cables in ducts across these bottoms, the 13.2-kv. outgoing feeders were carried a distance of one-half to one mile on pole lines with conductors supported on 25-kv. porcelain insulators. Lightning is particularly severe in this district and although the circuits, where they changed from overhead to underground construction, were all protected by oxide-film lightning arresters and some of them also had lightning arresters at the power station end, there were, during the five years from 1920 to 1924 inclusive, a total of six cases where lightning entered the power station over these circuits and damaged equipment in the building. There was also one case of a cable breakdown near the feeder exit bushing and another case where an operator pulled a wrong disconnecting switch near the exit bushing, both of which resulted in practically the same kind and amount of damage as that caused by the lightning.

In the majority of these cases the damage consisted of the breakdown of one or more current transformers followed by an arc which burned one or more feeder reactors and destroyed some of the disconnecting switches, primary and secondary wiring, insulating supports and compartment doors. Each of these cases of trouble caused the temporary loss of a feeder circuit and was accompanied by a momentary drop in voltage. In not one of the eight cases, however, did any of the auxiliary motors drop out of step.

This power station has also had one case of trouble in which the bus bars were directly involved. On August 4, 1922, during a period of construction work, an operator carelessly closed a disconnecting switch on a grounded oil circuit breaker which grounded the C-phase of the main bus bars. Three 20,000-kw. units were in service at the time, and the neutral of No. 3 unit was grounded through a 3-ohm resistor.

When the accident occurred, generator No. 3 was tripped out by its balanced relays. The operator then tripped off generators Nos. 1 and 2 thereby shutting down the entire system. A subsequent examination disclosed the following damage: The disconnecting switch, with which the operator established the ground, was burned up. The neutral resistor developed a ground and shunted out 5/7 of the resistance, permitting a current flow calculated at 8800 amperes as against a flow of 2500 amperes had all the resistance been in circuit. This excess current burned out and open-circuited that part of the resistor remaining in circuit. Two jumper connections between coils on the C phase of unit No. 3 burned open. Within 12 minutes the station was again in operation, and within 30 minutes the load was back to normal.

At no time in any one of the three Power Stations, even under the worst of short circuit conditions, has there been any trouble experienced from the shifting of cables and bus bars, or the breaking of bus bar and insulator supports by the mechanical forces which are usually characteristic of a heavy flow of uncontrolled short circuit current.

Based on the experience given above, the authors feel that short circuits in the largest power stations can be so controlled by a properly designed system of bus reactors that their destructive effects will be confined to the immediate vicinity of the arc. There will be some disturbance in voltage beyond the bus reactors, but in only the most severe cases will this be of sufficient magnitude to cause auxiliary motors to drop out of step. Furthermore, they feel that with properly chosen reactors, it will be possible to tie together power stations and power systems of any magnitude so that a short circuit will be of merely local significance, and will not jeopardize the service of the other parts of the system.

For assistance in compiling the information on short circuits, the authors are indebted to E. H. McFarland of the American Gas & Electric Company, Windsor, West Virginia, C. W. DeForest of the Union Gas & Electric Company, Cincinnati, Ohio, and Edwin Jowett of the Kansas City Power & Light Company, Kansas City, Missouri.

Self-Excited Synchronous Motors

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Associate, A. I. E. E.

Synopsis:—*The theory and applications of self-excited synchronous motors have been repeatedly discussed in the literature, but the subject has been usually presented as a study of some special variety of this type. It now seems timely to give an outline of the general theory of the subject as a basis of comparison of the proposed types and a starting point for further development work.*

The study of a self-exicted motor is mainly a study of its exciting system. The writer shows that any combination of the exciting circuits is equivalent to one comparatively simple type, and studies two problems in connection with this standard type; (1) determination of performance of a given motor; (2) determination of design constants giving a desired performance. In this study stress is laid on the elements peculiar to this type of motor; but no attempt is made to treat fully the elements which the self-excited motor has in common with other, better known, motor types. The current locus of the motor is found to be a circle, and it is shown that any circle in the plane can be obtained by a suitable choice of the exciting system.

The subject of synchronising is treated by a method showing an intimate connection between the synchronising process and the synchronous operation. The discussion of synchronising can thus be limited to the standard type, because the equivalence of the synchronous operation means also the equivalence of the synchronising features. It is shown that very high torque can be obtained during synchronising.

The theory is applied to a brief study of a few types of the self-excited motor.

DURING the last few years the increasing importance of a good power factor gave a fresh impetus to the study of the possibilities of synchronous motors. Naturally enough, the efforts of the inventors and manufacturers were directed primarily against the greatest drawback of synchronous motors—their poor starting characteristics; the result was the appearance of a number of "self-starting" synchronous motors of the Danielson type; these motors are structurally similar to the induction motors with phase-wound secondaries, and act as such during the starting period, but later are converted into synchronous motors by supplying one phase (or a combination of phases) of the secondary with direct current.

This type requires a separate source of excitation and is suitable only for large outputs; but it becomes increasingly evident that efforts are being made on many sides to extend the self-starting principle to the smaller sizes by making them self-excited. For this purpose the primary member carries in addition to the main a-c. winding a small d-c. type winding connected to a commutator; the secondary member carries a field winding and brushes bearing on the commutator and connected to the field winding. At synchronism the magnetic field is at rest with respect to the brushes; a continuous e. m. f. appears at the brushes and supplies the excitation. As in the Danielson motor, the secondary is of the polyphase type, with one or several phases used as the field winding.

In connection with the non-salient pole motors the principle of self-excitation was found to possess remarkable advantages which go far towards compensating for the complication of the commutator and brushes:

1. A synchronous motor develops a field of armature reaction whose direction and magnitude are determined by the load; since this field is stationary with respect to the secondary, *i. e.*, brushes, it is possible to make use of it in order to obtain some desired relation between the voltage at the brushes and the load; usually an increase of excitation with the load.

2. As the motor approaches synchronism, its induction motor torque approaches zero, and the final synchronization is accomplished by the synchronous torque. In a separately excited motor the synchronous torque, considered as a function of the coupling angle, is approximately alternating, with the average value zero; in a well designed self-excited motor the synchronous torque is pulsating, with the positive part far in excess of the negative part, *i. e.*, with a definite positive (motoring) average value; synchronizing becomes a very simple, entirely automatic process.

It was only natural that the first motors built or theoretically investigated were of the simplest kind: a single axis field winding and a single set of brushes[2]; in the great majority of cases this arrangement is quite satisfactory; but it is not the only possible form; motors with several angularly displaced field windings and brush sets possess some valuable features not obtainable with the single axis field winding. The added complication is not very great because the self-starting feature requires in any case several angularly displaced secondary windings (phases).

The self-excited motor is still in the first stages of development; as in the case of the single-phase commutator motor the experimental research is complicated by the great number of possible combinations of as yet unknown relative merit. The purpose of this paper is to systematize the subject by reducing this apparent variety to a few fundamental types, and to develop for these types a method of theoretical investigation such as should always go hand in hand with the

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2. A brush set will always mean two diametrically opposite brushes in a bipolar motor, or their equivalent in a multipolar motor. The theory, of course, holds good with any angle A between the brushes of a set, because, with sinusoidal fields, the voltage across them is in a constant ratio with the voltage across two diametrically opposite brushes standing on the line perpendicular to the bisector of A.

practical work if the waste of haphazard experimenting is to be avoided.

In the writer's opinion the graphical method is best adapted to give an idea as to the possibilities and limitations of a new motor type; the study is made on the basis of the current locus, and all the performance elements are derived from it. The subject is treated with the usual assumption of sine wave voltages and currents, uniform airgap, proportionality between the m. m. fs. and the fluxes, and the sinusoidal distribution of the latter.

Since the polyphase feature of the secondary is of importance only at starting, a perfect symmetry is not essential; in the matter of distribution of copper between the phases and the interconnection of windings the designer has a considerable freedom, which can be used to obtain a good wave of m. m. f. and a small loss in the field winding. The main a-c. winding, of any polyphase type, may be either interconnected with the d-c. winding or independent from it. As a rule, the advantages of interconnection are small in comparison with mechanical complications of bringing out a number of taps; in what follows the windings will be assumed independent and, for the sake of simplicity, the connection diagrams will show only the exciting circuits.

At present the practise is to use the rotor as the primary member, connected to the supply by slip rings; the d-c. winding and the commutator are then on the rotor; the field windings and the brushes are stationary; this arrangement is adopted in the figures of the paper. The inverted arrangement, however, has many points in its favor.

The flux F_f due to a field winding is proportional to the e. m. f. at the brushes connected to this winding; this e. m. f. is proportional to the component F_n of the total flux of the motor normal to the line of brushes; therefore, for each exciting circuit consisting of the d-c. armature winding, a set of brushes, and a field winding, there is a constant ratio between F_f and F_n. This ratio will be called "circuit constant;" in a motor with several field windings and sets of brushes each exciting circuit has a circuit constant. The calculation of these constants for given electric and magnetic circuits is very simple, and will not be considered here.

At synchronism the action of a field winding is fully determined by its circuit constant and the position of the brushes; but it must be remembered that in a self-starting motor the field winding is used as the secondary of an induction motor, and must be designed so as to give a safe open-circuit voltage at starting. It is found that even with high open-circuit voltages the proportions of the field winding are such that the d-c. exciting voltage is very low; the variable brush resistance causes a variation of the circuit constant, especially at light loads, when the voltage at the brushes is low. This may cause the observed performance points to deviate from the positions indicated by the theory. Another cause of discrepancy is that the brushes short-circuit coils moving in a magnetic field; the influence of the circulating currents cannot be determined by calculation.

In the most general case the motor may have any number of field windings and brush sets, the angular spacing of windings and sets being entirely arbitrary; but the theory is greatly simplified by the following remarks based on the assumptions stated above:

1. *Two field windings connected to the same brush set are obviously equivalent to a single winding connected to this brush set.*

2. *Any number of coaxial field windings 1, 2, etc., Fig. 1, connected to different brush sets 3, 4, etc., are equivalent to a single winding of the same axis connected to a suitably located brush set.* This will be proved for two coaxial windings, but the demonstration is quite general. Let F be the total flux of the motor, α, β, δ = angles counted from a fixed axis OX, and a, b, the circuit constants of the windings 1 and 2; the fluxes due to 2 and 1 are then $a\,F \sin(\delta-\alpha)$ and $b\,F \sin(\delta-\beta)$. The constant c of the equivalent circuit and the angle γ between OX and its brush line must satisfy the equation:

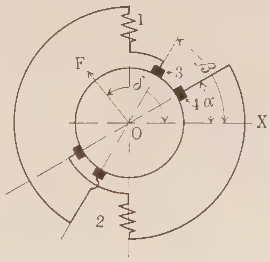

FIG. 1

$a\,F \sin(\delta-\alpha) + b\,F \sin(\delta-\beta) = c\,F \sin(\delta-\gamma)$ for all values of F and δ; this equation has always a solution: $c = \sqrt{a^2+b^2+2\,a\,b\cos(\alpha-\beta)}$; $\tan\gamma = (a\sin\alpha + b\sin\beta) \div (a\cos\alpha + b\cos\beta)$.

3. *An exciting system consisting of any number of angularly displaced field windings and brush sets is equivalent to two field windings acting along arbitrarily selected axes and connected to two suitably located brush sets.* For, by paragraph 1, each field winding can be resolved into two windings acting along two arbitrary axes and connected to the original brush set; and by the paragraph 2 each of these two sets of coaxial windings is equivalent to a single winding connected to a suitably located brush set.

The choice of the axes being arbitrary, it is possible to further simplify the problem without restricting its generality by taking a set of rectangular field axes.

To sum up: *The most general exciting system is equivalent to two field windings displaced 90 electrical degrees and connected to two angularly displaced brush sets.*[3]

3. It can also be shown that it is equivalent to two arbitrarily spaced brush sets connected to two suitably proportioned and located field windings.

This system will be studied in the paper. The equivalence of the synchronous performance means the equivalence of the synchronizing features, as will be shown below.

The fundamental difference between a motor with a single set of brushes or its equivalent (paragraph 2) and the general case is the fact that in the former the axis of the d-c. excitation remains fixed with respect to the brushes, while in the latter the resultant axis of the d-c. excitation moves relatively to the brushes. In what follows, these two classes of motors will be denoted as "fixed axis" and "variable axis" motors.

Fig. 2 shows the general form of the exciting system. It is determined by four arbitrary constants: two circuit constants of the field windings 1 and 2 and two constants determining the positions of the brush sets. Since it is impossible to tell beforehand what values of these constants are of practical importance, no restriction will be made in this respect. The geometrical figures are apt to be misleading in such a case, and it is necessary to adopt a convention of signs for the fluxes and the angles. Positive directions are assumed for all axes, and a component of a flux along an axis is always

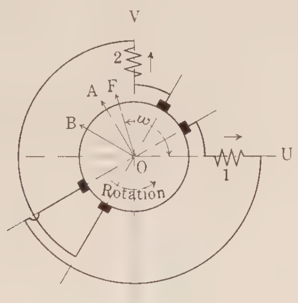

Fig. 2

taken with a sign. The positive directions of the field axes $O\,U$, $O\,V$, marked by the arrows, are denoted by $\overline{U}$, $\overline{V}$. The positive direction of angles and the rotation of the primary relative to the secondary are assumed counterclockwise. The angle between any two vectors $\overline{A}$ and $\overline{B}$ (or between the positive directions of two directed axes) is denoted by $(\overline{A}, \overline{B})$ or simply (A, B); it is positive or negative according as a rotation which makes $\overline{A}$ parallel to-and of the same direction as $\overline{B}$ is in the positive or negative direction of angles; thus, $(\overline{U}, \overline{V}) = \frac{\pi}{2}$. The angle between any two vectors $\overline{A}$ and $\overline{M}$ of a system of vectors $\overline{A}, \overline{B}, \overline{C}, \ldots \overline{L}, \overline{M}$, is given by the well known relation $(\overline{A}, \overline{M}) = (\overline{A}, \overline{B}) + (\overline{B}, \overline{C}) + \ldots + (\overline{L}, \overline{M})$.

The position of the brushes is determined as follows: let $\overline{A}$ and $\overline{B}$ be arbitrarily selected positive directions of the axes of the brush sets (axes perpendicular to the lines of brushes); the connections between the field windings and the brushes will be assumed such that, when the positive directions of the axes of a brush set and of the winding coincide, the action is as in a true self-excited motor, *i. e.*, an originally existing flux along the axis is then increased by the exciting current. With this convention the fluxes F_f and F_n whose ratio is the circuit constant have always the same sign, *i. e.*, the circuit constant is always positive. The position of the brushes is now fully determined by the angles $\alpha = (\overline{U}, \overline{A})$ and $\beta = (\overline{V}, \overline{B})$.

Let $\overline{F}$ be the vector and F = the numerical value of the flux of the a-c. armature reaction stationary with respect to the secondary; let ω be the angle $(\overline{U}, \overline{F})$; the components F_u and F_v of $\overline{F}$ along $O\,U$ and $O\,V$ are $F_u = F \cos(\overline{U}, \overline{F}) = F \cos\omega$, and $F_v = F \cos(\overline{V}, \overline{F}) = F \cos[(\overline{V}, \overline{U}) + (\overline{U}, \overline{F})] = F \sin\omega$. If F_1 and F_2 are fluxes set up by the windings 1 and 2, then the total fluxes along $O\,U$ and $O\,V$ are $F_u + F_1$ and $F_v + F_2$ (neglecting the small flux due to the currents in the d-c. armature winding), and the total flux along the brush axis $O\,A$ is $(F_u + F_1)\cos(\overline{U}, \overline{A}) + (F_v + F_2)\cos(\overline{V}, \overline{A}) = (F_u + F_1)\cos\alpha + (F_v + F_2)\sin\alpha$. Similarly, the total flux along $O\,B$ is $(F_u + F_1)\cos(\overline{U}, \overline{B}) + (F_v + F_2)\cos(\overline{V}, \overline{B}) = -(F_u + F_1)\sin\beta + (F_v + F_2)\cos\beta$. Let a and b be the circuit constants of the windings 1 and 2; their definition gives the equations: $F_1 = a[(F_u + F_1)\cos\alpha + (F_v + F_2)\sin\alpha]$ and $F_2 = b[-(F_u + F_1)\sin\beta + (F_v + F_2)\cos\beta]$. These equations, solved for F_1 and F_2, give: $F_1 = m_1 F_u + n_1 F_v$; $F_2 = m_2 F_v - n_2 F_u$, where

$$\left.\begin{aligned}
m_1 &= \frac{a\cos\alpha - a\,b\cos(\alpha - \beta)}{1 - a\cos\alpha - b\cos\beta + a\,b\cos(\alpha - \beta)}\\
m_2 &= \frac{b\cos\beta - a\,b\cos(\alpha - \beta)}{1 - a\cos\alpha - b\cos\beta + a\,b\cos(\alpha - \beta)}\\
n_1 &= \frac{a\sin\alpha}{1 - a\cos\alpha - b\cos\beta + a\,b\cos(\alpha - \beta)}\\
n_2 &= \frac{b\sin\beta}{1 - a\cos\alpha - b\cos\beta + a\,b\cos(\alpha - \beta)}
\end{aligned}\right\} \quad (1)$$

Substitution of the expressions of F_u and F_v found before gives

$$\left.\begin{aligned}
F_1 &= F(m_1\cos\omega + n_1\sin\omega)\\
F_2 &= F(m_2\sin\omega - n_2\cos\omega)
\end{aligned}\right\} \quad (2)$$

Let r and x be the primary resistance and leakage reactance per phase, and X = armature reactance corresponding to the flux F. Fig. 3 is the vector diagram of the motor. $O\,X_1$ and $O\,Y_1$ are rectangular axes, $O\,I'$ is the current I' per phase, $O\,A' = r\,I'$, $A'\,B' = x\,I'$, $B'\,C'$ = counter – e. m. f. $X\,I'$ due to the flux F, $C'\,M'$ = e. m. f. E_1 due to the flux F_1, $M'\,N'$ = e. m. f. E_2 due to F_2; $C'\,N'$ is the resultant counter – e. m. f. E, and $N'\,O$ is the applied voltage. The e. m. f.s. E_1 and E_2 are functions of ω; for a given ω their vectors $C'\,M'$ and $M'\,N'$ are found as follows:

it is seen in Fig. 2 that, with the adopted counter-clockwise rotation of the primary, a positive flux along $O\,U$ sets up an e. m. f. whose vector makes with the vector $B'\,C'$ an angle ω, laid off from $B'\,C'$ with due regard to the sign of ω; if the flux along $O\,U$ is negative, the vector obtained by this rule should be reversed. Hence the general rule; the numerical expression of an e. m. f. due to a flux along $O\,U$ in Fig. 2 is given the same sign as the flux; its vector in Fig. 3 is then obtained by laying off the algebraic value of the e. m. f. along a directed axis whose positive direction $\overline{L}$ is defined by the relation $(\overline{X}', \overline{L}) = \omega$. The rule for e. m. fs. due to the fluxes along $O\,V$ is similar, the positive direction $\overline{T}$ of vectors being defined by $(\overline{X}', \overline{T})$

$$= \omega - \frac{\pi}{2}.$$

Since the armature reaction flux F sets up an e. m. f. numerically equal to $X\,I'$, the algebraic values E_1 and E_2 of the e. m. fs. set up by F_1 and F_2 (*eq.* **2**) are

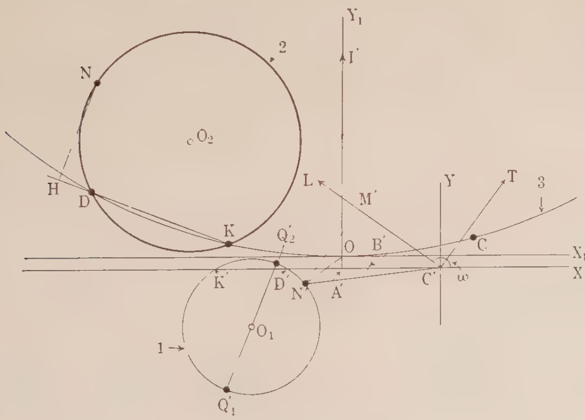

FIG. 3

$$\left.\begin{aligned} E_1 &= X\,I'\,(m_1 \cos\omega + n_1 \sin\omega) \\ E_2 &= X\,I'\,(m_2 \sin\omega - n_2 \cos\omega) \end{aligned}\right\} \quad (3)$$

If I' is kept constant, the point N' describes the locus of the applied voltage at constant current. Let $C'\,X'$ and $C'\,Y'$ be a set of coordinate axes with positive directions $\overline{X}'$ and $\overline{Y}'$ parallel to $\overline{X}_1$ and $\overline{Y}_1$; the projections of the vectors $\overline{E}_1$ and $\overline{E}_2$ on $C'\,X'$ are $E_1 \cos(\overline{X}', \overline{L}) = E_1 \cos\omega$ and $E_2 \cos(\overline{X}', \overline{T}) = E_2 \sin\omega$. Their projections on $C'\,Y'$ are $E_1 \cos(\overline{Y}', \overline{L}) = E_1 \sin\omega$, and $E_2 \cos(\overline{Y}', \overline{T}) = -E_2 \cos\omega$; therefore, the coordinates x' and y' of the point N' are

$$\left.\begin{aligned} x' &= E_1 \cos\omega + E_2 \sin\omega \\ y' &= E_1 \sin\omega - E_2 \cos\omega \end{aligned}\right\} \quad (4)$$

From these two equations E_1 and E_2 can be obtained and substituted in eq. (**3**); this gives:

$$x' \cos\omega + y' \sin\omega = X\,I'\,(m_1 \cos\omega + n_1 \sin\omega)$$
$$x' \sin\omega - y' \cos\omega = X\,I'\,(m_2 \sin\omega - n_2 \cos\omega)$$

The elimination of ω between these equations gives

$$\begin{vmatrix} y' - n_1\,X\,I' & x' - m_1\,X\,I' \\ x' - m_2\,X\,I' & -y' + n_2\,X\,I' \end{vmatrix} = 0$$

which can be written:

$$(x' - x_c')^2 + (y' - y_c')^2 = R^2 \quad (5)$$

with

$$x_c' = \frac{X\,I'}{2}\,(m_1 + m_2) \qquad y_c' = \frac{X\,I'}{2}\,(n_1 + n_2),$$

$$R = \frac{X\,I'}{2}\,\sqrt{(m_1 - m_2)^2 + (n_1 - n_2)^2} \quad (6)$$

This shows that the locus of the point N' is a circle 1 of center (x_c', y_c') and radius R. Therefore, the current locus at constant voltage E_0 is another circle 2 of center O_2, obtained from circle 1 by inversion with O as center and $E_0\,I'$ as constant of inversion, followed by a rotation over 180 deg. around $O\,I'$.

In what follows the corresponding points in the constant current (*c. c.*) and constant voltage (*c. v.*) diagrams will be denoted by the same capitals with and without accent, respectively. The same convention will be applied to the applied voltage E_0, current I and e. m. fs. E, E_1, and E_2 at the corresponding points of the two diagrams, so that

$$I = I' \times \frac{E_0}{E_0'} \qquad E = E' \times \frac{E_0}{E_0'} \text{ etc.}$$

PART 1. DETERMINATION OF PERFORMANCE OF A MOTOR OF GIVEN CONSTANTS

The constants of a motor are r, x, X, a, b, α, β. Instead of the last four it is convenient to use m_1, m_2, n_1, n_2, because they have an important geometrical meaning: the points Q_1' of coordinates $X\,I'\,m_1$ and $X\,I'\,n_1$, and Q_2' of coordinates $X\,I'\,m_2$ and $X\,I'\,n_2$ are diametrically opposite points on the circle 1, as can be proved by the substitution in the eq. (**5**), and by observing that x_c' and y_c' are coordinates of the middle point of the segment $Q_1'\,Q_2'$.

Construction of the current locus. Torque. The current locus 2 can be drawn as follows: let $p\,I'$ and $q\,I'$ be coordinates (with reference to $C'\,X'$ and $C'\,Y'$) of any point N' of the *c. c.* diagram: the coordinates with respect to $O\,X_1$ and $O\,Y_1$ are $(p + x + X)\,I'$ and $(q - r)\,I'$; the applied voltage $N'\,O$ is $I'\,\sqrt{(p + x + X)^2 + (q - r)^2}$ and the corresponding point N of the locus at the applied voltage E_0 can be found by observing that the current vector $O\,N$ is equal to $\dfrac{E_0}{\sqrt{(p + x + X)^2 + (q - r)^2}}$, and is symmetrical to $O\,N'$ with respect to $O\,X_1$, *i. e.*, it makes with $O\,X_1$ an angle δ such that $\tan\delta = \dfrac{q - r}{p + x + X}$.

By this rule the two points Q_1 and Q_2 corresponding to

Q_1' and Q_2' can be obtained. Moreover, the line $O\,O_2$ makes with $O\,X_1$ an angle η such that

$$\tan \eta = \frac{y_c' - r\,I'}{x_c' + (x+X)\,I'} = \frac{X\,(n_1 + n_2) - 2\,r}{X\,(m_1 + m_2 + 2) + 2\,x};$$

the center O_2 is the intersection of $O\,O_2$ with the perpendicular bisector of $Q_1\,Q_2$.

The circle diagram shows clearly the difference between the motors with fixed and variable axes of excitation. In the former $b = O$, so that $m_2 = n_2 = O$, *i. e.*, the circle 1 pases through the fixed point C', independent of the exciting system. The current locus 2, therefore, always passes through the fixed point C; theoretically C is the no-load point of the induction motor having the same r, x and X. The motor with a variable axis of excitation is free from this limitation; in fact, as will be shown, any circle in the plane can be obtained by a suitable choice of constants.

At D' and K' the torque is zero because the resultant e. m. f. $E = C'\,N'$ is normal to the current $O\,I'$; in the *c. v.* diagram the points of zero torque are D and K, on the inverse of the line $O\,X'$, *i. e.*, on a circle 3 of radius $\frac{E_0}{2\,r}$, tangent to $O\,X_1$ at O and having its center on $O\,I'$.

It is known that in the *c. v.* plane the loci of points of constant power transferred from the primary to the secondary are circles concentric with the circle 3 which corresponds to zero torque; the radius of the circle corresponding to the torque of P synchronous watts is

$$\sqrt{\left(\frac{E_0}{2\,r}\right)^2 - \frac{P}{r}}.$$

These circles are convenient for comparison of polyphase motors having the same r, whether synchronous or induction type, because they represent the torque regardless of the type of the rotor. The torque at any point N is proportional to the distance $N\,H$ from the line $D\,K$. These theorems are well known; their proof can be found in the article 2 of the bibliography.

The torque comprises the friction torque and the torque exerted by the field on the d-c. winding; the latter, expressed in synchronous watts, is the power consumed in the exciting circuits.

The circle 1 intersects $C'\,X'$ only if $R > |\,y_c\,|$, *i. e.* if $(a \cos \alpha - b \cos \beta)^2 > 4\,a\,b \sin \alpha \sin \beta$. This condition is always satisfied in motors with a fixed axis of excitation ($b = O$); but motors with a variable axis can be designed so that $R < |\,Y_c\,|$ as will be shown; such a motor has not only a maximum torque, but also a minimum torque, below which the synchronous operation is not possible.

Analytical expression of the torque. Maximum torque. Let $\theta = (\bar{L}, N'\,O) = (\bar{L}, \bar{E}_0')$ be the angle between the vector $N'\,O = \bar{E}_0$ of the applied voltage and $\bar{L}$, which may be considered as a directed axis attached to the secondary member; then

$$(\bar{T}, \bar{E}_0') = (\bar{T}, \bar{L}) + (\bar{L}, \bar{E}_0') = \frac{\pi}{2} + \theta;$$

$$(\bar{I}', \bar{L}) = (\bar{I}', \bar{X}') + (\bar{X}', \bar{L}) = -\frac{\pi}{2} + \omega;$$

$$(\bar{I}', \bar{T}) = (\bar{I}', \bar{L}) + (\bar{L}, \bar{T}) = \omega - \pi.$$

Projecting the closed line $O\,A'\,B'\,C'\,M'\,N'\,O$ on the directions $\bar{L}$ and $\bar{T}$ it is found with the aid of the foregoing relations:

On $\bar{L}$: $-r\,I \sin \omega + (x+X)\,I \cos \omega + E_1 = -E_0 \cos \theta$

On $\bar{T}$: $r\,I \cos \omega + (x+X)\,I \sin \omega + E_2 = E_0 \sin \theta$

With E_1 and E_2 from eq. (**3**) these equations, solved for $I \sin \omega$ and $I \cos \omega$, give:

$$\left.\begin{aligned} I \sin \omega &= E_0\,(A \cos \theta + B \sin \theta) \\ I \cos \omega &= E_0\,(A' \cos \theta + B' \sin \theta) \end{aligned}\right\} \quad (7)$$

where

$$A = -\frac{X\,n_2 - r}{C}, \quad B = \frac{x + X + X\,m_1}{C},$$

$$A' = -\frac{x + X + X\,m_2}{C}, \quad B' = -\frac{X\,n_1 - r}{C}$$

and $C = (X\,n_1 - r)\,(X\,n_2 - r) + (x + X + X\,m_1)\,(x + X + X\,m_2)$.

The torque per phase in synchronous watts (considering a motoring torque as positive) is $-\,I'E_1 \cos(\bar{I}'\,\bar{L}) - I\,E_2 \cos(\bar{I}', \bar{T}) = -\,I\,E_1 \sin \omega + I\,E_2 \cos \omega$. The negative torque acting on the d-c. winding is the power consumed in both exciting circuits; it can be represented by $k_1\,E_1^2 + k_2\,E_2^2$ (k_1 and k_2 = constants referred to one phase, whose numerical values can easily be calculated from the electrical and magnetic data of the motor). This assumption disregards the fact of the superposition of the two exciting currents in the d-c. winding; but the loss in it is relatively very small. The torque per phase T exerted on the shaft is $T = -\,I\,E_1 \sin \omega + I\,E_2 \cos \omega - k_1\,E_1^2 - k_2\,E_2^2$. The substitution of E_1 and E_2 from eq. (**3**) gives: $T = -X\,I^2\,(f \sin^2 \omega + g \cos^2 \omega + h \sin \omega \cos \omega)$, with $f = n_1 + k_1\,X\,n_1^2 + k_2\,X\,m_2^2$; $g = n_2 + k_2\,X\,n_2^2, + k_1\,X\,m_1^2$, and $h = m_1 - m_2 + 2\,k_1\,X\,m_1\,n_1 - 2\,k_2\,X\,m_2\,n_2$. With $I \sin \omega$ and $I \cos \omega$ from eq. (**7**) this becomes $T = -\,X\,E_0^2\,(p \sin^2 \theta + q \cos^2 \theta + t \sin \theta \cos \theta)$, where $p = f\,B^2 + g\,B'^2 + h\,B\,B'$; $q = f\,A^2 + g\,A'^2 + h\,A\,A'$; and $t = 2\,f\,A\,B + 2\,g\,A'\,B' + h(A\,B + B\,A')$. Finally, let an angle θ_0 be defined by the relations

$$\sin 2\,\theta_0 = \frac{p - q}{\sqrt{(p-q)^2 + t^2}} \text{ and } \cos 2\,\theta_0 = \frac{t}{\sqrt{(p-q)^2 + t^2}}$$

then $T =$

$$-\frac{X}{2}E^2{}_0\left[(p+q)+\sqrt{(p-q)^2+t^2}\times\sin 2\,(\theta-\theta_0)\right] \tag{8*}$$

The extreme values of the torque are

$$-\frac{X}{2}E_0{}^2\,[p+q\pm\sqrt{(p-q)^2+t^2}].$$

E. m. fs. E, E_1, and E_2 in the Circle Diagram. E_1 and E_2 determine the loss in the field windings. Fig. 4

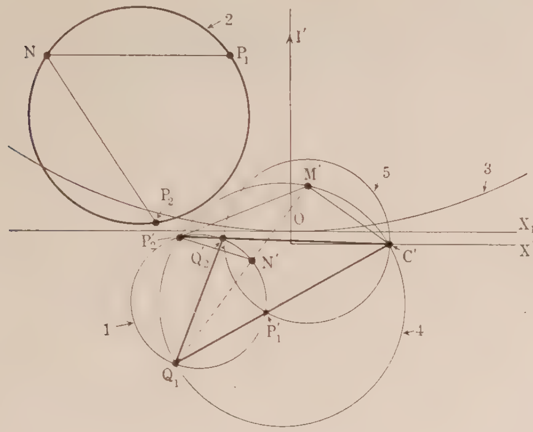

Fig. 4

reproduces some essential parts of Fig. 3. The points Q_1' and Q_2' have for coordinates $(X\,I'\,m_1,\,X\,I'\,n_1)$ and $(X\,I'\,m_2,\,X\,I'\,n_2)$. On the basis of eq. (3) it can easily be seen that when ω varies the ends of the vectors $\overline{E}_1'$ and $\overline{E}_2'$ drawn from C' move on the circles 4 and 5 described on $C'\,Q_1'$ and $C'\,Q_2'$ as diameters, and that these diameters pass through the common points P_1' and P_2' of the circles 1 and 5, and 1 and 4. For a given point M' on 4 the vectors $\overline{E}_1'$ and $\overline{E}_2'$ are $C'\,M'$ and $M'\,N'$ respectively; if N' moves on the circle 1, the angles of the triangle $P_2'\,M'\,N'$ remain constant because two of them are subtended by constant arcs $Q_1'\,P_2'$; therefore, there is a constant ratio between the segment $P_2'\,N'$ and the vector $M'\,N'$ of E_2. Let N, P_1 and P_2 be the corresponding points in the *c. v.* diagram. By the well known property of the inverse points

$$P_2\,N = P_2'\,N'\times\frac{\text{inversion const.}}{O\,P'_2\times N'\,O}$$

$$= P_2'\,N'\times\frac{E_0\,I'}{O\,P_2'\times N'\,O}\,.$$

But P_2' is a fixed point, so that $O\,P_2' = I'\times$ constant, where the constant depends only on the constants of the motor; as shown above $P_2'\,N'$ is proportional to the e. m. f. E_2' at voltage E_0', and $N'O = E_0'$; therefore,

$P_2\,N$ is proportional to $\dfrac{E_2'\times E_0\,I'}{I'\times E_0'}$ = proportional to

$E_2'\times\dfrac{E_0}{E_0'}$ = proportional to E_2. By the same reasoning, the segment $P_1\,N$ is proportional to the e. m. f. E_1. The coefficients of proportionality can be found as follows: the segment $C'\,N'$ represents the resultant e. m. f. E' of E_1' and E_2'; but

$$C\,N = C'\,N'\times\frac{E_0\,I'}{O\,C'\times N'\,O}$$

$$= C'N'\times\frac{E_0\,I'}{I'\sqrt{r^2+(x+X)^2}\times E_0'}$$

$$= \frac{E}{\sqrt{r^2+(x+X)^2}}$$

i. e., C N represents the resultant e. m. f. E. When the point N coincides with P_2, the e. m. f. E_2 vanishes; $C\,P_2$ and $P_1\,P_2$ represent then the same e. m. f. E_1; therefore, for every point N,

$$E_1 = P_1\,N\times\frac{C\,P_2}{P_1\,P_2}\sqrt{r^2+(x+X)^2}\,;$$

similarly,

$$E_2 = P_2\,N\times\frac{C\,P_1}{P_1\,P_2}\sqrt{r^2+(x+X)^2}\,.$$

The expression $E = C\,N\sqrt{r^2+(x+X)^2}$ shows that for given r, x and X the total e. m. f. due to the field

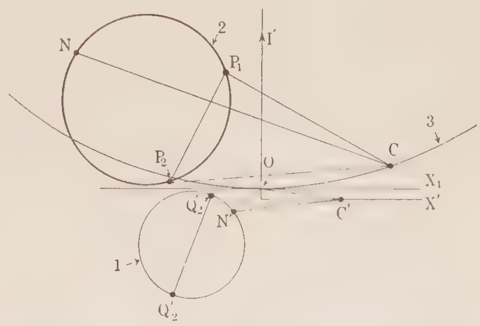

Fig. 5

windings is constant at a given point N, regardless of the locus to which N may belong. This remark should be borne in mind when choosing the working region of the plane for a new motor. It may also be noted that

$O\,C = \dfrac{E_0}{\sqrt{r^2+(x+X)^2}}$, *i. e.*, $O\,C$ represents the applied voltage E_0 at the same scale as $C\,N$ represents the resultant e. m. f. E.

*Starting from this formula the performance can be determined entirely by calculation: it gives θ for a definite output; equations (7) give I and ω; the e. m. fs. E, and E_2 result from eq. (3); the power factor $\cos\varphi$ is given by the relation $(\overline{I}',\overline{N}'\,O) = (\overline{I}',\overline{X}')+(\overline{X}',\overline{L})+(\overline{L},N'\,O) = -\dfrac{\pi}{2}+\omega+\theta$, hence $\cos\varphi = \sin(\omega+\theta)$.

Stability. When the load increases the rotor falls back, *i. e.*, the angle θ increases. In general, the operation can be stable only on the part of the circle where an increase of θ corresponds to an increase of the torque. The eq. (**3**) and (**4**) give, after elimination of E_1 and E_2 and a few simple transformations: $x' - x_c = R \cos (2\,\omega - \epsilon)$ and $y' - y_c = R \sin (2\,\omega - \epsilon)$, where ϵ is a constant; R and $2\,\omega - \epsilon$ can be considered as the polar coordinates of the circle 1 with its center as origin and $2\,\omega - \epsilon$ as the polar angle. This shows that when the point N' moves on the circle 1 in a definite direction, the sense of the variation of $2\,\omega - \epsilon$ (therefore, of ω) remains the same.

Since the coordinates of C' relative to $O\,X_1$ and $O\,Y_1$ are $(x + X)\,I'$ and $-\,r\,I'$, the expressions of A, B, A' and B' in eq. (**7**) show that their nominators are proportional to the coordinates of Q_1' and Q_2' relative to $O\,X_1$ and $O\,Y_1$. Let a_1, b_1, and a_2, b_2, denote these coordinates; equations (**7**) give by division

$$\tan \omega = \frac{b_2 \cos \theta - a_1 \sin \theta}{a_2 \cos \theta + b_1 \sin \theta}\,;$$

hence, after some transformations,

$$\frac{d\,\omega}{d\,\theta} = -\,\frac{(a_1\,a_2 + b_1\,b_2)\cos^2 \omega}{(a_2 \cos \theta + b_1 \sin \theta)^2}\,.$$

But $a_1\,a_2 + b_1\,b_2$ is the scalar product of $O\,Q_1'$ and $O\,Q_2'$ and has the sign of $\cos \angle\, Q_1'\,O\,Q_2'$ which is positive or negative according as the point O is outside or inside of the circle 1, because $Q_1'\,Q_2'$ is a diameter. Therefore, when N' moves on the circle 1 in the clockwise direction (decreasing ω), θ increases if O is outside of the circle, and decreases if O is inside. The locus 2 is obtained from 1 by an inversion and a rotation over 180 deg. around $O\,Y_1$; if O is outside of 1, each operation reverses the rotation of N once; if O is inside of 1, only the last operation reverses the rotation. As O is either inside of both circles 1 and 2, or outside of both, it follows that the clockwise motion of N on the locus 2 always corresponds to an increase of θ: *the stable operation corresponds to that part of the current locus on which the point of maximum torque is reached from the point of zero torque by a motion in the clockwise direction.*

Part 2. Determination of the Exciting System for a Given Current Locus

The constants r, x and X will be assumed as known. Let a circle, such as 2 in Fig. 3, be a locus, presumably within the capacity of the motor; it is desired to check this assumption by determining the exciting system and the excitation losses.

Since a circle is an inverse figure of itself, it is convenient to take for the constant current locus 1 a circle symmetrical of 2 relative to $O\,X_1$. The value of the constant current I' is obtained from the fundamental relation of the inverse points, by drawing any convenient secant. The points A', B' and C' can now be located as in Fig. 3. Let $Q_1'\,Q_2'$ be an *arbitrary* diameter; it follows from what was found in part 1 that, if the coordinates (with respect to $C'\,X'$ and $C'Y'$) of the points Q_1' and Q_2' be divided by $B'\,C' = X\,I'$, and the quotients substituted for m_1, m_2, n_1 and n_2 in eq. (**1**) the numbers a, b, α and β in these equations are the constants giving the locus 2. The solutions of these equations are

$$\left.\begin{aligned}
a &= \frac{\sqrt{n_1^2 + (m_1 + G)^2}}{S}, \\
\sin \alpha &= \frac{n_1}{\sqrt{n_1^2 + (m_1 + G)^2}}, \\
\cos \alpha &= \frac{m_1 + G}{\sqrt{n_1^2 + (m_1 + G)^2}} \\
b &= \frac{\sqrt{n_2^2 + (m_2 + G)^2}}{S}, \\
\sin \beta &= \frac{n_2}{\sqrt{n_2^2 + (m_2 + G)^2}}, \\
\cos \beta &= \frac{m_2 + G}{\sqrt{n_2^2 + (m_2 + G)^2}}
\end{aligned}\right\} \quad (\mathbf{9})$$

where $S = 1 + m_1 + m_2 + m_1\,m_2 + n_1\,n_2$; $G = m_1\,m_2 + n_1\,n_2$, and the radicals are taken with the signs giving positive values for a and b. The roots are always real; therefore, theoretically, *there always exists an exciting system giving any desired locus in the plane.* In fact, the problem has an infinity of solutions because the diameter $Q_1'\,Q_2'$ is arbitrary. The study of the constants a, b, α, β, corresponding to different diameters is facilitated by the following remarks: (1) since $Q_1'\,Q_2'$ is a diameter, S and G are independent from the choice of $Q_1'\,Q_2'$ because they are proportional to the scalar products $\overline{B'\,Q_1'} \times \overline{B'\,Q_2'}$ and $\overline{C'\,Q_2'} \times \overline{C'\,Q_1'}$ respectively; (2) the radicals in (**9**) are proportional to the distances of Q_1' and Q_2' from a fixed point on the axis $C'\,X'$ whose abscissa (with respect to C') is $x' = -\,X\,I' \times G$; the coefficient of proportionality $X\,I'$ is the same as for G and S. For instance, in the case when the circle 1 passes through C' (*i. e.*, $G = O$), let Q_2' coincide with C'; this gives $m_2 = n_2 = O$, $b = O$; the motor has a fixed axis of excitation and a single field winding; if Q_1' and Q_2' are different from C', the condition $G = m_1\,m_2 + n_1\,n_2 = O$ gives $\cos (\alpha - \beta) = O$, $\alpha - \beta = \dfrac{\pi}{2}$, *i. e.*, the brush sets coincide and are equivalent to a single set; the motor has two field windings connected to the same brush set and is equivalent to the first case.

Synchronising. When a motor, carrying a reasonable load as an induction motor, comes up to speed, the slip of the rotor is low and the conditions are similar to the synchronous performance with the rotor gradu-

ally falling back under the influence of the load. The torque is the sum of the induction torque and the synchronous torque, the latter passing through a sequence of values corresponding to a complete cycle of synchronous performance represented by the current locus. In a separately excited motor the torque is nearly alternating, with a small negative average value; in a self-excited motor, however, the choice of the locus is arbitrary; if the exciting system is such as to give a circle similar to Figs. 9 or 11, entirely or for the most part inside of the circle 3, *i. e.*, in the region of positive (motoring) torques, the torque during the synchronising process either remains positive, or is mostly positive, with a small negative interval of short duration. Analytically, the synchronizing torque is expressed by eq. (**8**).

A commercial synchronous motor must have a synchronous no-load point, *i. e.*, the circles 2 and 3 must have common points; the pulsations of the current and of the torque are inavoidable during the synchronising process, whether the axis of excitation is fixed or variable; but in the latter case it is possible to adjust the constants (for instance, the position of brushes) temporarily so as to throw the locus toward the center of the circle 3 in the region of the high-torque points of the plane, and out of contact with 3; and to reduce its diameter; in this way the synchronising torque may be considerably increased and the pulsations reduced until the motor reaches synchronism, when, with a little care, the change back can be accomplished without causing an undue shock to the system.

Part III. Examples

It is intended here to pass rapidly in review some of the types of the self-excited motor and to show that, with the aid of the diagrams and formulas of the paper, an idea as to the possibilities and limitations of a type can often be obtained without any extensive calculations. This study is facilitated by observing that, since the angle of two curves remains unchanged by the inversion, the angle γ between the circles 2 and 3 is the same as between the circle 1 and the line $A'\,X'$; it is given by $\cos\gamma = \dfrac{y_c'}{R}$, eq. (**6**).

1. *Fixed Axis of Excitation.* In all motors of this class it can be assumed that $b = O$, $m_2 = n_2 = O$, so that $\cos\gamma = \dfrac{n_1}{\sqrt{m_1^2 + n_1^2}} = \sin\alpha$, *i. e.*, $\gamma = \dfrac{\pi}{2} - \alpha$. All fixed axis motors pass through a fixed point C, the no-load point of the induction motor having the same r, x and X.

Example 1. Brushes on neutral axis, Figs. 6 and 7. In this case $\alpha = O$, $\gamma = \dfrac{\pi}{2}$, the circle 2 is normal to the circle 3. For comparison. let $2'$ be the locus of an induction motor of the same constants r, x and X; $2'$ is also normal to the circle 3 (see, for instance, Journal, A. I. E. E., April 1921, p. 326). If both motors have the same maximum torque, 2 and $2'$ are tangent to the same constant torque circle $3'$ and, if the synchronous motor is designed for leading power factor, as shown, the excitation must be so strong that its no-load current $O\,D$ is of the same order of magnitude as the locked current of the induction motor. More-

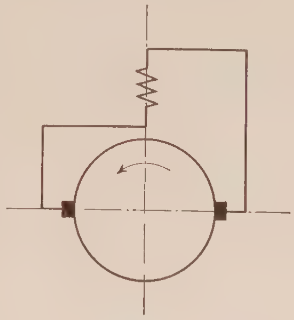

Fig. 6

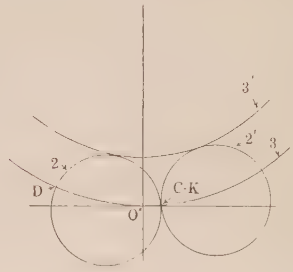

Fig. 7

over, the synchronous torque which is proportional to the distances of the points of the circle to the line K-D is very nearly alternating, so that the synchronising characteristics are very poor.

Example 2. Brushes on the axis of the fieldwinding, Figs. 8 and 9. Here $\gamma = O$; the circles 2 and 3 are tangent. The torque is always positive (motoring); the synchronising features are excellent, but the motor

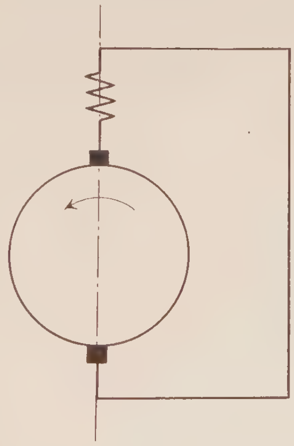

Fig. 8

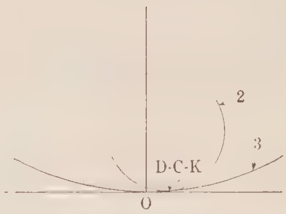

Fig. 9

is very sensitive to the brush position, and the power factor at light loads is not as good as can be expected in a synchronous motor.

The correct setting of the brushes is as in Fig. 10, intermediate between Figs. 6 and 8, but nearer to the latter than to the former. The locus is then as in Fig. 11.

2. *Variable Axis of Excitation.* Example 3: One might be tempted to improve the starting characteristics and to simplify the construction by using two identical exciting circuits displaced 90 deg. against one

another; but in this case $a = b$, $\alpha = \beta$; hence, $m_1 = m_2$, $n_1 = n_2$, therefore $R = O$ eq. (**6**): the circles 1 and 2 collapse each into a point; the synchronous performance is simply the synchronous point of a more general, variable speed performance of the motor.

Example 4. Fig. 12. The windings are connected to the brushes so that $\alpha = O$, $\beta = \pi$; 1 is the exciting winding proper, while 2 opposes the transverse armature reaction. Equations (**1**) give $n_1 = n_2 = O$, therefore, $\cos \gamma = O$, $\gamma = \pi/2$; the locus 2 is normal to the circle of zero power 3, as in the example 1, Figs. 6 and 7, but is not restricted to pass through C; the synchronising torque is alternating, therefore, the synchronising characteristics are poor.

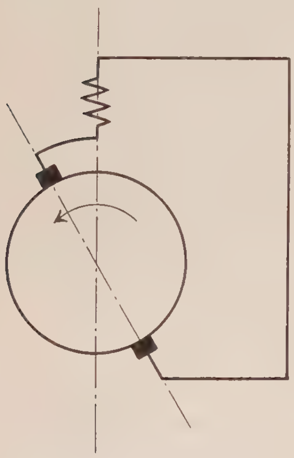

FIG. 10

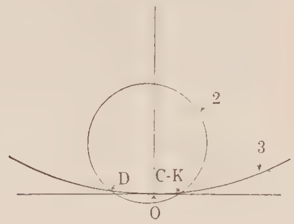

FIG. 11

Example 5. Fig. 13. Both windings act along the lines of brushes, $\alpha = \beta = \pi/2$; if the windings are indentical, the locus is a point, as explained above; if a is not equal to b, the locus is a circle, but, since the condition $(a \cos \alpha - b \cos \beta)^2 > 4\, a\, b \sin \alpha \sin \beta$ cannot be satisfied, this circle has no common points with the circle 3: the motor has no synchronous zero torque points.

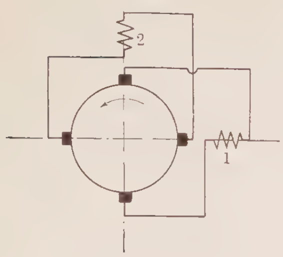

FIG. 12

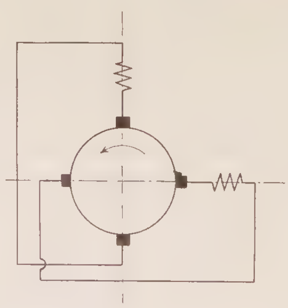

FIG. 13

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BETTER INDUSTRIAL HEATING DATA ARE NEEDED

It is hardly surprising that so rapidly growing and useful an art as industrial electric heating should be handicapped in these earlier days of development by inadequate data. Wherever specialists in this field foregather this lack is voiced. Descriptions of installations are plentiful and complete enough, and these serve a necessary purpose in exchanging reports on practises and showing prospective customers physical realities, but the "before and after" economic data so urgently desired by both manufacturers and central-station companies are pitifully scarce. We believe that the situation will improve from now on, but progress will indeed be slow unless heating problems are attacked with true scientific thoroughness by engineers responsible for the success of equipment design and applications.

Electric heating engineers are not responsible for past failures of prospective customers to keep reliable cost records of process fuel costs prior to the advent of electrical methods, and yet some fair degree of accuracy in estimating these must be attained if the economic justification of the electrical installations is to be "followed through." Far too little is known about the cost of handling fuel oil from tank car to burner (this averages 1.5 cents per gallon in one large company with many plants in the East), about the quantities of fuel used in specific processes, about the accurate labor content and maintenance expenses of individual manufacturing and treating operations under many conditions, about the prorated overhead costs of operations and apparatus which the electric heating engineer plans to supersede or improve, and about the cost of spoilage or of damaged work under conditions of poor control frequently associated with non-electrical methods.

Permission to install suitable measuring devices should be sought wherever feasible before the older installation is abandoned in favor of electricity, and here is a great field for the co-ordination of resources among power and heating engineers. It is quite as important to obtain heating data from such installations before changing over as to indicate reciprocating engines and study heat balances in analyzing plants for possible motor driving. It goes without saying that adequate records of time cycles, production volume, energy consumption, etc., should follow the application of industrial electric heating so far as practicable. Through the interchange of more complete data the whole art will advance more surely and more rapidly, customers will be better served, and sounder progress will be guaranteed.—*Electrical World*.

Cooperative Course in Electrical Engineering of the Massachusetts Institute of Technology

BY WM. H. TIMBIE[1]

Fellow, A. I. E. E.

Synopsis:—*There is no standard cooperative plan of education. A cooperative course takes on the ideals, purposes and standards of the school and companies cooperating.*

The purpose of the Massachusetts Institute of Technology is to give young men well grounded knowledge and specialized information combined with a broad education and the power to apply theories of science to the practical requirements of industry. The cooperative course in Electrical Engineering at M. I. T. naturally has the same ideals and purpose.

The course is five years in length and offers a degree of Master of Science to those who complete it. Only the last three years are cooperative, the first two years being practically identical with the regular Electrical Engineering Course.

The regular school year consists of two terms and a summer vacation. The cooperative year includes the summer in its schedule and has three terms to the year, two of them being coterminous with the regular Institute terms. During the last three years the cooperative students spend every other term (practically four months) at the plants of the cooperating companies, any one student always going to the same company. The practical experience thus occupies eighteen months of carefully selected and supervised work in the industries. The student has the choice of a manufacturing company or a public utility company, providing he meets the Institute standard in scholarship and the company's standard in personality and natural inclination. He is paid at an hourly rate depending upon his length of service with the company, each student earning about $1500 during the three years. The last year is spent upon post graduate study and research both at the Institute and with the company. The student is under no obligation to stay with the company after graduation nor is the company obliged to hire him. To date, 47 per cent of the men have remained with the cooperating company.

While at the plants of the cooperating company, the student continues to carry two of his Institute studies, two evening classes per week being conducted by members of the instructing staff at the Institute.

Main features. 1. The course aims to train a carefully chosen group for engineering service of the particularly high order, in manufacturing and public service companies.

2. The theoretical part of the regular Electrical Engineering course has not been cut in order to make room for the engineering practise. On the contrary a year of post-graduate work has been added, for which a degree of Master of Science is granted.

3. The Engineering practise for a student consists of a course of experience, carefully planned and supervised. It is not merely a series of jobs.

4. The student spends all of his cooperative periods in the employ of one company getting a unified conception of organization and company policy. He learns the meaning of team work and loyalty.

5. Fluctuating business conditions do not interfere with his engineering practise.

6. The practical experience reacts on his theoretical work, explaining it and making it real to him.

7. His theoretical studies are not interrupted during his practise periods. He gets the habit of working days and studying nights, a habit which experience proves is hard to break in later years.

THE cooperative plan in education is not a new idea. It has long been recognized both in America and abroad that there are certain advantages in an educational scheme which enables a student to obtain his practical experience along with his technical and scientific training. In 1906, Dean Schneider started the cooperative plan at the University of Cincinnati, and during the last 19 years the scheme has been introduced into one school after another. It has not been confined to technical schools or to colleges and universities; a number of high schools are operating this plan more or less successfully. It has been tried out in all types of educational institutions from high schools to colleges of liberal arts. At Antioch College under Dr. Morgan is a notable example of its introduction into a liberal arts college. Inasmuch as the cooperative scheme is adaptable to schools ranging in grade from high school to college and from trade schools to colleges of liberal art, there can be no such thing as a standard cooperative course. There are as many different types of cooperative courses as there are schools and colleges offering such courses. A cooperative plan is merely one in which the school cooperates with the industries in teaching and training the students. The grade and type of a cooperative course is determined by the grade and type of the school offering the course, together with special ideals and traditions of the individual school. The object of a cooperative course in a trade school is to give those being trained the very best preparation for careers as highly skilled artisans, inspectors, and foremen, but it has different objects in the Engineering schools and colleges of liberal arts. President Morgan says, "The object of the cooperative work at Antioch is to bring about a balanced development of character, intelligence and power."

Because the Massachusetts Institute of Technology is a school having certain ideals and traditions and demanding a certain grade of scholarship, the cooperative course in electrical engineering at this institution has certain individual and characteristic ideals which are peculiar to it individually. For that reason it was thought that a description of the cooperative plan at the Massachusetts Institute of Technology would prove of interest to the American Institute of Electrical Engineers.

General Purpose

The purpose of the Massachusetts Institute of Technology is to give young men well-grounded knowl-

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edge and specialized information combined with a broad education and the power of applying theories of science to the practical requirements of the industries. Accordingly, the cooperative course in electrical engineering has these same ideals. It aims to give to men with these qualifications a start on the road to important positions in two distinct parts of the electrical field, the manufacturing industries and in public utilities. For the purpose of developing the highest scientific engineering and administrative capacities of men who wish to become leaders in manufacturing industries, the Institute operates a course in conjunction with the General Electric Company. In order to afford a definite professional education and training for both technical and executive work in public utilities companies, cooperative courses are given in conjunction with the Edison Electric Illuminating Company of Boston, The Boston Elevated Railway, and Stone and Webster, Inc. These companies are notable in their progressiveness and efficiency and are of sufficient size to afford experience and training in all the important departments of the industry. In five years the enrollment on these courses has grown from 27 students to over 200.

Plan of Operation

In brief, the outline of the plan is as follows:

The course covers a period of five years, the first two years being practically identical with the first two years of the regular Electrical Engineering course at the Institute. The last three years are divided equally between instruction at the Institute and practical training at the plants of one of the cooperating companies. The instruction by the Institute staff, during the first four years of the course, is similar in method and content to the instruction in the regular Electrical Engineering course. The training at the plants is laid out and conducted with a view to the maximum educational value and is intimately correlated with professional instruction at the Institute.

The work of the fifth or final year consists of graduate work in Electrical Engineering. In the manufacturing option emphasis is placed during this year on problems of administration of large manufacturing enterprises, the design and development of engineering projects and creative research. In the public utility option emphasis is on the problems of administration of public utilities, together with research on technical, scientific and administrative problems incident to the conduct of the affairs of such enterprises. Considerable latitude may be exercised in the assignment of men to posts in engineering and research departments with a view to utilizing and developing individual aptitudes. The last period of the fifth year is spent by both groups at the Institute so that the men are here during the graduation period. The schedule of any one student for the last three years is to spend alternate terms of four months at the Institute and at the works, with a four weeks' vacation each year.

The periods spent at the plants by the students have been three months in length and alternated with eleven weeks' periods spent at the Institute and a two weeks' vacation every six months. This plan provided for four shifts a year and made the students' periods at the Institute coterminous with the regular Institute terms. Next year the Institute changes over to a two term basis. This will divide the year into three terms each, so that the students' stay at the Institute will be coterminous with the regular semesters of the Institute calendar, and will require but three changes a year.

Each class is divided into two equal sections, one section being at the Institute while the other is at the Works. This makes the number of men at the plants always the same. It will be noted that the length of the cooperating periods is considerably greater in the Massachusetts Institute of Technology plan than in most institutions. The Institute believes that a period of this length has the following decided advantages over short periods and no disadvantages.

1. Since the course is not out of joint with the rest of the Institute, the men are able to enter into the student activities at the school. The benefit gained by students' participation in student activities is too well known to have to be defined before this group.

2. A four months' period at the works allows sufficient time for the student to gain a real knowledge of the conduct of a department and enter into its spirit. Where departments do not require so much time as this, it is very easy to split up the term between two or more departments.

3. At every change there is some slack to be taken up. Reducing the number of changes to three or four a year reduces this slack to a minimum.

4. It was feared by some that if the students stayed away from the Institute for so long a period, they would lose the habit of application to their studies. This objection does not apply to the M. I. T. scheme because all the while the student is at the works he is continuing two of his regular Institute studies. Members of the instructing staff conduct regular classes for these men in the class rooms of the works, or at the Institute in the evening when the men are located in the vicinity of Cambridge. Far from being a detriment to the course, this has proved of decided advantage. It has provided time for twelve more courses of study which could not be crowded into the terms which the students spend at the Institute.

We are already hearing from employers of graduates of this course comments to the effect that it has become perfectly natural for the men to put in several evenings a week studying on problems which come up in their daily work. If the cooperative course accomplishes nothing but just this one thing, it far more than justifies its existence. Too many graduates of engineering schools on graduation day put their books on the shelf and say, "Thank Heaven I'm through with those." The successful graduate is the man who

continues the habit of study and research. Very few men in the regular course have ever had the experience of working in the office, shop, or field during the daytime and studying during the evening, and it naturally comes hard for them to start. The cooperative course by compelling a man to do this for three years makes it a habit with him which is not easily broken.

Selection of the Men

The men who are accepted for this course must be of exceptional calibre because they are required to meet two standards. *First,* they must maintain a clear record for the first two years in their studies at the Institute: *Second,* their personal qualifications must be such as to convince the representatives of the company that they are the type of men that is likely to succeed with the company. The last point is judged by means of a personal interview with each student. About the middle of the student's second year at the Institute, he is interviewed individually by representatives of the cooperating companies. Generally these representatives consist of men from the Personnel and Employment Departments. The applicants are marked on their past experience, their conduct, initiative, self-reliance, and general appearance. This method of choosing has resulted in the selection of men of unusual ability.

Content of the Course

At the Institute the men pursue what is practically the regular Electrical Engineering course. In addition to this they have three graduate courses in advanced Electrical Engineering, a graduate seminar and write a thesis of Master-of-Science grade. For the successful completion of this work, the student receives a degree of Master of Science as well as Bachelor of Science. We believe that a man comes to the Institute to become well grounded in theory. The course, therefore, is a strictly theoretical and scientific one. Little time is taken up in teaching engineering practise.

The manufacturing practise is taken at the works of the General Electric Company. The course here is as carefully laid out as the work at the Institute, so that the student will have a well grounded experience in the field which he choses. He is not made a tester only or a draftsman only but is assigned to the machine shop, armature winding, drafting, motor testing, turbine test, Research Laboratories, factory production, etc. In addition to the general assignments, each man has at least one assignment in the department in which he wishes to specialize. Those men desiring experience on electric locomotives and railway appliances are sent to Erie; those wishing to specialize on transformers are given a term at Pittsfield; and those wishing to specialize on heavy rotory machines are assigned to Schenectady.

In the public utility companies the experience with the Edison Electric Illuminating Company of Boston includes practise in the Electrical Engineering office, maintenance of Line Department, locating and repairing trouble in low- and high-tension lines, both overhead and underground, in the steam division and electrical division of the Generating Department, obtaining experience in boiler room repairs, firing and testing, operating and repairing of electrical equipment; in the Installation Department, testing meters and maintenance of street lighting system and service to customers; in the sales department, learning office methods, rate computing, power estimating and commerical engineering; in the supply department, learning the purchasing, receiving, inspection, and shipping of goods; in the Standardizing and Testing Departments, becoming familiar with the standardizing of various types of electrical equipment, and making steam, chemical, and electrical tests of the property and equipment.

With the Boston Elevated Railway, a student goes through the Maintenance Department and Track Department, where he acquires experience in track building and welding; in the Equipment Division, where he becomes familiar with tie and timber treatment; and in the Rapid Transit Department, getting acquainted with the steel maintenance and erection division, signal division, and building division. He works in the Architectural and Civil Engineering Departments; in the Department of Rolling Stock and Shops, with its experience in the car house pits, the rapid transit shop, armature shop, machine shop, and truck shop; in the Transportation Department, where he acts as switchman, motorman, conductor, and studies time tables and traffic. In the Power Department he obtains experience in the Wire and Conduit Division, in the Power Station and Substations and Electrical Engineering work. Finally, he spends five weeks in the General Manager's office getting a bird's eye view of the whole property.

With Stone and Webster, a student spends part of one term in the Messenger Service becoming acquainted with the engineers and executives of the company; in the Drafting Department, working on electrical, steel, mechanical, concrete and architectural drawings; in the Construction Department he actually assists in the surveying, in erecting foundations, concrete construction and steel work, and in making mechanical and electrical installations; in the Statistical Department, analyzing and tabulating construction and operating data of various jobs, also doing some cost accounting; in the Operation Department, operating gas plants, electrical power plants, gaining experience in the boiler house, and with generating and switching apparatus. His final assignment is in that department of the company in which he wishes to specialize.

Students are not shifted from one company to another but stay with the same company throughout the three years of the cooperative course. He does not promise to stay with the company after the three years nor does the company promise to take him. It

is understood, however, that, throughout the three years of the cooperative course, he will be put through practically the course outlined. During these three years, a student must continue to maintain a clear record in his studies and must have more than an average rating with the company. He is dropped from the course if he fails to meet the company's standards or the Institute standards.

Students, while with the company, are rated as regular employes and are subject to the usual requirements as to physical examination, etc. Compensation is made by the company to the students at an hourly rate amounting approximately to a total payment of $1500 during the cooperative period. The working week in the shops is usually 48 hours and in the offices 44 hours, which provides for Saturday half-holidays in both cases.

Coordination

In order to keep the wheels of cooperation and coordination between the Institute and the company well oiled and running smoothly, a member of the instructing staff spends two afternoons a week at the plant of the cooperating company, interviewing the foreman and superintendent under whom the men are working and checking up with the students themselves the actual experience acquired. In this way the instructing staff also keep themselves informed as to how the particular industry is conducted and what changes are taking place within the industry and become intimately acquainted with the executives and artisans.

The knowledge and experience gained in this way is immediately useful in the classes which are conducted two evenings a week at the plant. One of these classes is a course in Electrical Engineering where there is great opportunity for introducing the material coordinating plant practise and modern theory. The other course is of a more general nature. There are five of these given at the works:

1. A course in the appreciation of contemporary English and American Literature.
2. A course in Modern Business Correspondence.
3. Business Psychology.
4. Corporation Accounting.
5. Preparation and Presentation of Reports and Technical Papers. This course is unique and unusually effective. A brief description of it is not out of place. The object is to enable the engineering student to arrange his data and arguments logically and to present them effectively and convincingly. For this purpose the class is formed into a Committee or a Board of Conferees, one of the students presiding and two or three others acting as a sub-committee to present a technical report on an engineering project. After a discussion by the class the project is voted upon and either accepted or rejected. One of the students, acting as Secretary, writes a report of the meeting and the students presenting the project are required to prepare a written report of their presentation. During the term each student has an opportunity to serve on two sub-committees, to preside over a meeting twice, and to act as Secretary twice. In all these general studies, a great mass of material is introduced coordinating the practise and policy of the companies with the modern theories of science and business administration.

Real Cooperation

The spirit in which the cooperating companies take hold of their end of the task is perhaps best illustrated by the following. The superintendents of the General Electric Company have arranged a schedule among themselves whereby, once a week, one of the superintendents has the students come to his office and, in an informal way, talks to them for an hour concerning the details of the work of which he is in charge. Sometimes the students are taken through the shops of the department where special exhibits of the work have been prepared showing the material in different stages of manufacture and arranged in order of the processes. At other times this is taken care of by lantern slides. When it is understood that this feature was introduced into the course at the suggestion of the superintendents and is given entirely upon the superintendents' own time, you may appreciate to what extent the individual men in the cooperating companies enter into the spirit of the work. Of course, with such examples and incentives for giving the best that is in them, you may be sure that the students strive to do their share. They enter heartily into the spirit and work of the shops and offices and quickly become a part of the company. Particular attention is given to impressing the student with the great factor which the human element represents in their chances of success. They soon come to understand the sterling qualities of the men with whom they are working and study to adapt themselves to the personal characteristics and eccentricities of the various foremen under whom they are working, experience which will be of the utmost importance to them when they have arrived at a position where they are directing the work of others. So, during their period at the plants, they secure experience not only in Electrical Engineering but also in what is called for lack of a better name, "Human Relations." They learn to estimate the strength and characteristics of men as well as the strength and properties of materials.

Results

The cooperative plan may be compared to a system of physical training in which intense physical exercise is alternated with periods of lighter but regular exercise which keeps the athlete at all times on the tips of his toes. We have merely to substitute the word "mental" for the word "physical" in the above sentence to make it apply to the cooperative work. The fine mental condition of the students in these classes is a source

of constant comment at the Institute. An arrangement of this kind certainly makes them more alert, more wide awake, and gives them a keen appetite for study, as well as broadening their interest in life. So, from the standpoint of the Institute and the students, this plan is a decided success.

From the companies' point of view the results of the course have been satisfactory, in that it has attracted to the company some of the most capable graduates of the Institute. To date, the number of students from this course going with the cooperating companies is 46 or approximately 47 per cent of those who have taken the course. When it is remembered that these students, in the first place, were members of a carefully selected group and that they have been again selected as being outstanding men in these groups, it will be seen that the company has succeeded in securing men who ought to possess exceptional qualities of brain and character and in only very rare instances have the men failed to come up to these expectations. In the Manufacturing Industry, the course has had a decided tendency to turn men who are particularly fitted for it into the design and manufacturing fields where their theoretical knowledge and scientific training can be best utilized.

Conclusion

There are seven distinct original features, in the operation of this course, which we believe are educationally sound.

1. This cooperative course is not for the purpose of training artisans or foremen but for attracting to the manufacturing and public utility industries of the country the highest type of engineering student, and affording him a broad foundation for his chosen career with an early start in the work for which he finds himself especially adapted. It is hoped that the manufacturing industries will find many of their research and designing engineers from the product of this course and that the public utilities will find among the graduates, men who have a knowledge of the latest scientific developments and a habit of clean-cut scientific analysis and logical inference for their executive and administrative positions.

2. The practical experience obtained at the works does not displace any theoretical study. All practical experience is in addition to the regular Electrical Engineering course in theory and science; in fact, this course goes one step further in that it gives one year of advanced electrical theory over and above what is usually given in a four year Electrical Engineering Course.

3. The practical experience in manufacturing engineering and in public utility practise is as carefully planned and supervised as the student's work at the Institute. For the manufacturing industry it constitutes a progressive course in shop work, design, production, testing and creative research. For the public utilities it constitutes a progressive course in shop work, laying out and planning, operating, testing, management, and research into the particular problems confronting a public utility company. That is, the practical work is selected and arranged to constitute a course of experience just as the studies in science and theory at the Institute are selected and arranged so that they constitute a course in Electrical Engineering. A mere sequence of jobs would not provide proper experience nor would it constitute a course any more than a mere sequence of unrelated studies would constitute a course of Electrical Engineering.

4. There is afforded an excellent opportunity to do some real training in team work and in the development of a sense of loyalty to the job. These are prime requisites for any successful engineer. If these qualities are not gained, the most rigorous intellectual training is wasted. This is the reason why a student receives all of his practical experience with one company where he can be given a unified conception of the organization and a real appreciation of the policies and spirit of the company.

5. The study of science and theory are continuous; it is not interrupted when a student goes to the cooperating company. The Institute maintains regular classes for students while they are located at the various plants, these classes being taught by members of the Institute instructing staff. The habit of evening study during the time of employment is perhaps one of the most valuable things gained from the course. A successful engineer must continue systematic habits of study in order to be able to bring to bear upon his daily problems the modern discoveries and developments in science.

6. Fluxuating business conditions do not interfere with the student's training by compelling him to omit some of his cooperative periods due to business depressions. The course is operated under the mutual agreement between the students and the company that the student will remain with the company throughout the three years of the course and that the company will provide the practical experience of the course during these three years.

7. Contact with actual conditions in his profession and acquaintance with engineers and workmen give the student a real background and a true prospective for his theoretical and scientific work at the Institute. The problems in science and engineering become real problems to him and not merely classroom exercises. His association with all kinds of men at the plant has taught him the value of the human element in engineering which often takes years for a technical graduate to learn.

It is estimated that the Province of Bavaria can produce approximately 2,000,000 horse power of hydroelectric energy, of which 540,000 horse power, or 27 per cent, has already been developed. Another 50 plants, with a total of 50,000 horse power, are under construction, while 145 plants, totaling 400,000 horse power, are contemplated.

Echo Suppressors for Long Telephone Circuits

BY A. B. CLARK[1]
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and

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Synopsis.—*A device has been developed by the Bell System for suppressing "echo" effects which may be encountered under certain conditions in telephone circuits which are electrically very long. This device has been given the name "echo suppressor" and consists of relays in combination with vacuum tubes, which are operated by the voice currents so as to block the echoes without disturbing the main transmission.*

This paper gives a brief description of this device, together with a discussion of its possibilities and limitations. A number of echo suppressors have been operated on commercial telephone circuits for a considerable period so that their practicability has been demonstrated.

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Introduction

In designing telephone circuits which are electrically very long, an important problem is presented by the necessity of avoiding serious "echo" effects. Echo effects are caused by reflections of voice waves which take place whenever electrical irregularities are encountered in telephone circuits. The effects produced are very similar to echoes of sound waves. Some of the reflected waves return to the receiver of the talker's telephone so that if the effects are severe, he may hear an echo of his own words. Other reflected waves enter the receiver of the listener's telephone and, if severe, cause the listener to hear an echo following the directly received transmission.

Reflections of voice waves occur in all practical telephone circuits. It is only in telephone circuits of such length as to require a number of repeaters, however, that echo effects become serious. The fact that the circuits are electrically very long makes the time lag of the echoes appreciable. At the same time, the telephone repeaters overcome the high attenuation of these long circuits and, consequently, make the echoes louder. The seriousness of the effect is a function both of the time lag and the volume of the echoes relative to the direct transmission.

A brief discussion of these echo effects was given in a paper[3] presented before this Institute about two years ago, and in a later paper[4] some examples of their relative effects in practical telephone circuits were given. In these papers the importance of keeping electrical irregularities within proper limits was pointed out as was also the advantage gained by using circuits having a high velocity of propagation so that the lag of the echoes is reduced.

As a supplement to these methods, a device to which has been given the name "echo suppressor" was developed by the Bell System, along lines suggested by John Mills[5]. In all practical telephone circuits involving more than a single repeater there are points where the transmission in the two directions passes through two separate paths. At these points the direct transmission passes through one path while only reflected currents or echoes pass through the other. The echo suppressor is located at one of these points. In this device, the voice currents, with the help of vacuum tubes, are caused to actuate relays which cut off the echoes in the return path without disturbing the other path through which passes the main transmission.

This paper, after briefly reviewing the nature of echo effects in four-wire circuits, explains, in a general way, how an echo suppressor functions on such a circuit. The four-wire echo suppressor is then described together with some variations in its design for use under special conditions and with other circuits. This is followed by a discussion of the possibilities and limitations of echo suppressors, both on four-wire and other types of telephone circuits.

Review of Nature of Echo Effects in Four-Wire Circuit

Fig. 1 illustrates the way echo currents may be set up and circulate in a four-wire circuit. In this figure, *a* shows a four-wire circuit in diagrammatic form. The squares at the extreme right and left are intended to represent the telephone sets used by two subscribers at the terminals *W* and *E*. The squares marked *N* represent electrical networks which simulate or balance, more or less perfectly, the impedances of the two telephone lines terminating in the instruments at *W* and *E*. In the four-wire circuit, the squares with arrows represent one-way repeaters. At each terminal the two separate one-way circuits comprising the four-wire circuit are joined together by means of the familiar balanced transformers. When *W* talks, the transmis-

1. American Telephone and Telegraph Co., New York City.
2. Bell Telephone Laboratories, Inc., New York City

3. "Telephone Transmission over Long Cable Circuits" by A. B. Clark, Transactions A. I. E. E., Vol. XLII, Page 86.

4. "Telephone Transmission over Long Distances" by H. S. Osborne, Transactions A. I. E. E., Vol. XLII, Page 984.

Presented at the Spring Convention of the A. I. E. E., St. Louis, Mo., April 13-17, 1925.

5. U. S. Patent No. 1,434,790, John Mills, "Two-Way Transmission with Repeaters." Issued Nov. 7, 1922.

sion passes directly to E over the upper pair of wires in the four-wire circuit, while, when E talks, the direct transmission passes over the lower pair of wires.

Below the diagram of the four-wire circuit is given another diagram *b* showing the path of the direct transmission as well as the paths of the echoes which are set up when W talks to E. The heavy line in the diagram represents the path of the direct transmission through the upper pair of wires in the four-wire circuit.

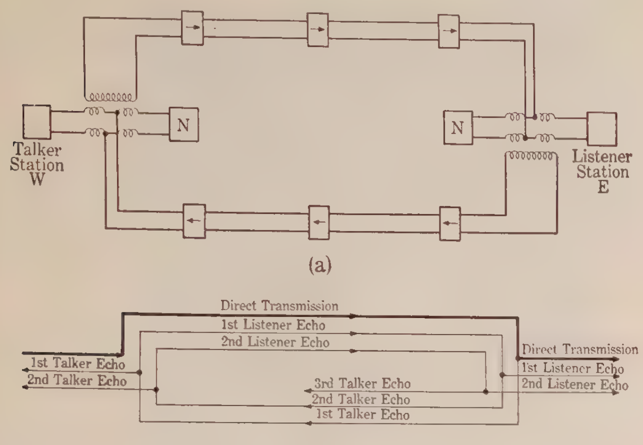


FIG. 1—ECHOES IN FOUR-WIRE CIRCUIT

In a practical four-wire circuit it might require, say, 0.05 second for the voice currents to make this journey. This would be the case if the four-wire circuit were 1000 miles (1600 km.) long in cable with extra-light loading—coils of 0.044 henry spaced 6000 feet (1.8 km.) apart. Cable circuits loaded in this way have a velocity of propagation of about 20,000 miles (32,000 km.) per second.

When the voice currents reach the distant end of the four-wire circuit, the larger part goes to the listener at E. If the balance between the line and network at the distant terminal is not perfect, however, a portion of the currents will travel back over the lower pair of wires toward W as an echo. This echo will, in the case assumed, reach the receiver of the telephone at station W, 0.1 second after the original voice wave is impressed on the line at that station. The path of this echo is labeled "1st Talker Echo." It is evident that if this echo is loud enough it may seriously distract the talker.

If the balance between the line and the network at Station W is also not perfect, part of this first echo will travel back over the upper pair of wires to Station E, the path of this echo being labeled "1st Listener Echo." The listener at E will hear this echo, if strong enough to be audible, 0.1 second after he hears the direct transmission. Evidently, if this echo is sufficiently loud as compared to the direct transmission, it will cause difficulty in understanding.

When the "1st Listener Echo" arrives at the end of the four-wire circuit, there is still another reflection of part of the current which occurs producing the "2nd Talker Echo."

This process is repeated, producing successive echoes which are received at both terminals W and E as indicated, the successive echoes getting weaker and weaker.

ACTION OF ECHO SUPPRESSOR ON FOUR-WIRE CIRCUIT

An echo suppressor will now be applied to the four-wire circuit and consideration given to its action and to its effect on the echoes. Fig. 2 shows a four-wire circuit which it will be assumed is exactly like the one shown in Fig. 1, with the exception that an echo suppressor has been applied to it. As before, the diagram *a* shows the four-wire circuit, while, below this, another diagram *b* shows the paths of the direct transmission and of the echo.

In Fig. 2a the echo suppressor is shown in very simple diagrammatic form. It will be described later in detail. For the present it is sufficient to explain that the echo suppressor consists of two similar high-impedance vacuum tube amplifier-detectors bridged across the two sides of the four-wire circuit, each amplifier-detector having associated with it a relay which operates whenever alternating voltage of sufficient strength is impressed across the input. The operation of either relay places a short circuit across the side of the four-wire circuit opposite to the one to which the input of its particular amplifier-detector is connected. This short circuit blocks the transmission flowing in one side of the four-wire circuit and, at the same time, renders the other amplifier-detector inoperative.

Normally, the contacts of the two relays are open,

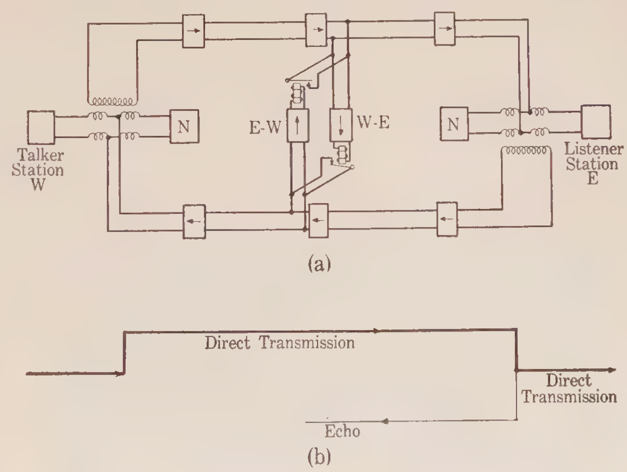


FIG. 2—ECHO SUPPRESSOR CUTTING OFF ECHO IN FOUR-WIRE CIRCUIT

so that talking may be done in either direction over the circuit. When W begins to talk, the condition illustrated in the figure is produced. W's voice currents, when they reach the middle of the circuit, cause the relay associated with amplifier-detector W-E to operate, thus placing a short circuit across the lower pair of wires in the four-wire circuit. The direct transmission from W to E is not affected at all, passing on to Station E where it is heard by the listener. The echo, which

starts back from Station E, travels toward Station W as far as the point where the echo suppressor is connected to the circuit. It is stopped there, however, by the short circuit which the echo suppressor has applied.

In the same way, when E talks, his voice currents actuate the amplifier-detector marked E-W and apply a short circuit to the upper pair of wires, thus preventing the passage of the echo current around the circuit.

The circuit shown in Fig. 2a is one of the more convenient for satisfying the fundamental operating conditions of an echo suppressor. These may be stated as follows: When no one is talking, free paths should exist for transmission in either direction and each suppressing relay should be ready to act at the passage of speech over the side of the circuit with which it is associated. When speech passes in one direction over the circuit the resulting operation of the corresponding half of the suppressor should not only interrupt the continuity of the opposite side of the circuit, but at the same time prevent the other half of the suppressor from functioning. The latter condition is desirable as otherwise the returning echo might have enough energy at times to operate the opposite part of the suppressor circuit and so interrupt the direct transmission. Outside of this restriction the selection of the points from which the echo suppressor input currents are derived and the points at which the relay control functions are applied is governed only by such considerations as economy of apparatus and convenience. In general, it is the more economical arrangement to have a single relay, which interrupts the path through which the echoes return, also remove the speech input from the suppressor by such a relative association of parts as shown in Fig. 2a.

It will be noticed that, as a finite time is needed for the switching operation, there is a possibility, if the two subscribers begin talking simultaneously, of both halves of the suppressor being operated together and remaining operated, with both sides of the circuit cut off, for a time equal to the release time of the relays. However, for the times of operation and release, which are found desirable from other considerations, it has been found that no apparent difficulty has been caused by this effect.

Because of the fact that an appreciable time is required for the voice currents to travel, it will be seen that exceedingly fast operation of the relays is not necessary. In the example given, if it is assumed that the echo suppressor is connected to the circuit at its midpoint, the echo requires 0.05 second to reach the point where the short circuit is applied, after the voice currents reach the input of the amplifier-detector. The echoes will be cut off by the relays, therefore, even if the latter require as long as 0.05 second for operation. If the echo suppressor is nearer to the end of the four-wire circuit this operating time would need to be somewhat shorter. In practical four-wire circuits it is seldom that an operating time shorter than about 0.02 second is required. It is an easy matter to secure this speed of operation with standard telephone relays.

The diagram also shows that, in order to completely cut off the echo, the echo suppressor relay must not open, after talk ceases, until the complete train of echoes has reached the point where the short circuit is applied. In the example given, the length of time required to reach the point where this relay applied the short circuit after the voice currents pass the input of the amplifier-detector is 0.05 second. It is seldom that this lag is greater than 0.1 second in practical four-wire circuits.

It is seen from the above two paragraphs that it is desirable for a four-wire echo suppressor to possess a moderately short operating time and a longer releasing time. How this is accomplished will be described in what follows.

Description of Four-Wire Echo Suppressor

In Fig. 3 is shown a circuit diagram of one-half of the echo suppressor, which is shown complete but in less detail in Fig. 2a. It consists of two vacuum tubes operating in tandem, the first functioning as an ampli-

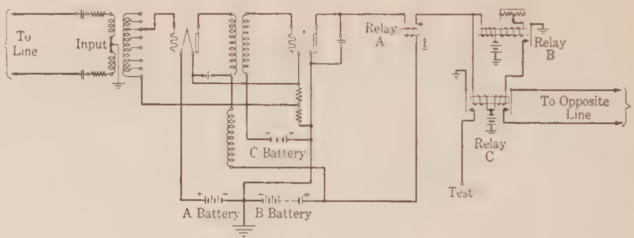


Fig. 3—Circuit Diagram of One-Half of a Four-Wire Echo Suppressor

fier and the second as a combined amplifier and detector.

As was shown in Fig. 2a the voltage impressed on this amplifier-detector combination is derived from speech currents passing over one side of the circuit, while the relay controlled by this combination short-circuits the other half of the circuit.

The voltage input to the amplifier tube is supplied through a transformer which is broadly tuned by series condensers to produce a circuit efficient at the more important voice frequencies but inefficient at other frequencies, particularly below 500 cycles per second. The circuit thus functions to minimize the effect of noise currents on the operation of the relays. Likewise, in the interstage transformer coupling, emphasis has been placed on securing the maximum voltage step-up to the detector grid in this same frequency region. To avoid any harmful reaction upon the transmission characteristics of the main circuit which might result from bridging on an input circuit whose impedance varies so greatly over the speech frequency range, this circuit is arranged to have a high impedance. The input transformer is also provided with a series of taps

on one of the windings, thus affording a simple means of varying the sensitivity of the device.

The detector tube is operated with a sufficiently large negative grid potential to reduce its space current to zero, or nearly so, when no input is applied to the circuit. Accordingly, relay A which is connected in the plate circuit is normally in a released condition. When speech currents are applied to the circuit the voltage on the grid of this tube fluctuates. Those variations which make the grid more negative produce no effect but those which make it more positive allow pulses of current to pass through relay A, tending to operate it. A condenser is bridged from plate to filament of this tube, the purpose of which is to average these rectified half waves of applied speech so as to insure smooth and positive operation of the relay.

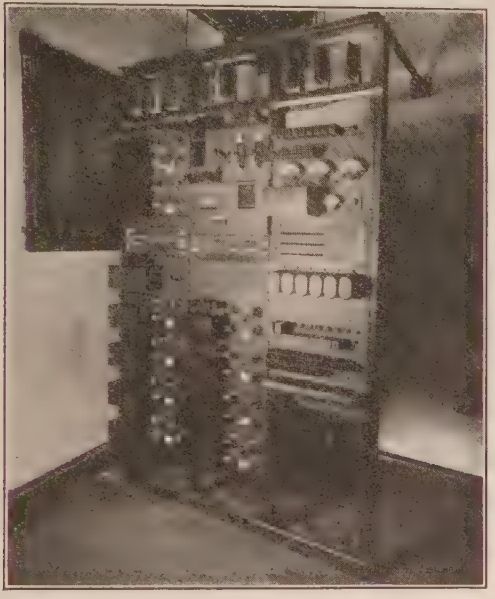


Fig. 4—Installation at Harrisburg, Pa.

When speech is applied to the circuit the resulting operation of relay A does two things. It causes the operation of relay C by connecting a ground to one of its windings, and it likewise operates relay B. The operation of relay C short circuits the opposite line. The time required for the operation of relay C, in response to a sustained alternating e. m. f. suddenly applied to the input of the amplifier detector, is about 0.02 second. As was pointed out above, operation in this length of time takes care of conditions in the large majority of cases encountered on four-wire circuits.

The function of relay B is to provide a delay in the release of relay C after speech has ceased to be applied to the suppressor circuit input and relay A has released. Its operation in response to that of A, it will be noticed, connects ground to a second winding on relay C which will then in turn remain operated as long as the relay B maintains this auxiliary current after the relay A has released. Relay B is made slow releasing by an auxiliary winding closed through a low resistance, and its time of release can be adjusted over a considerable range to meet different operating conditions by changing the value of this resistance. Differing adjustments are rarely called for in practise and these relays are normally set for a releasing time of 0.1 second.

A number of echo suppressors have been installed at Harrisburg, Pa., where they are now in service on a group of four-wire circuits. Fig. 4 is an illustration of this installation of four-wire echo suppressors. Fig. 5 shows a close-up view of an individual panel from the front. Both halves of the suppressor working on a single circuit are mounted together on one panel. The method of mounting and the type of equipment in the echo suppressors are in general quite like the standard for the four-wire circuits with which they operate. Although in Fig. 3 the battery supply circuits are shown individual to this set, in the actual installation common batteries are used. The four filaments of the tubes on one panel are operated in series from the 24-volt battery.

The operation and maintenance of these devices involve little that is different from standard repeater equipment. There is one test, however, which is employed in checking the times of functioning that perhaps deserves special mention. This test involves observing the time needed for the suppressor to go through any number of complete cycles of operation and release. To make this test, the short-circuiting contacts of relay C and the input of the suppressor circuit are connected together and to an oscillator as shown in Fig. 6. As soon as the oscillator is connected to the input, the relay train begins operating and the shorting contacts of relay C in turn cut off the applied voltage. This short circuit is maintained across the input for a time by the slowness of release of relay B as previously explained. When it finally releases and in turn

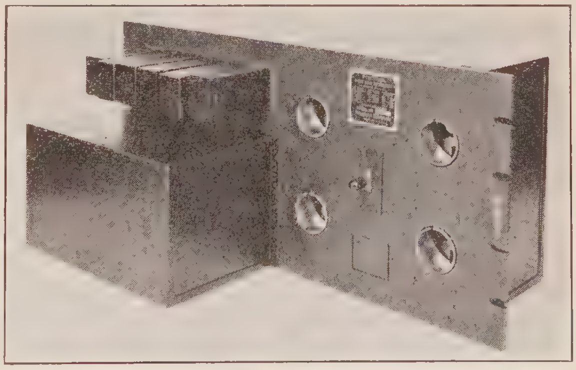


Fig. 5—Front View of Echo Suppressor Panel

releases relay C, the suppressor again operates and the process is repeated over and over. At each repetition of the cycle the auxiliary contacts of relay C apply a ground to the test terminal which is connected to a counting device. With the aid of a stop-watch the number of cycles in any given time is readily determined and thus the time of a single cycle of operation.

This time is the sum of the time needed for relays A and C to make and the time needed for relays A, B and C to release. By observing the uniformity and smoothness of operation with which this cycle is carried out the tester can check the adjustment of all the relays. If relays A and C are properly adjusted so that their operation is positive and uniform, the operating time

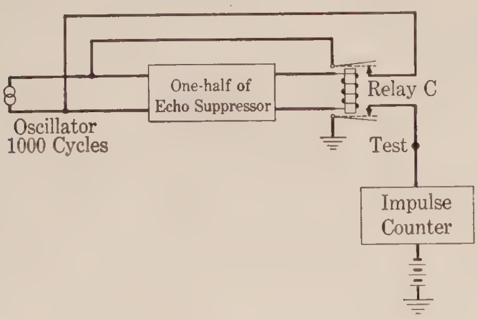


FIG. 6—CIRCUIT FOR TESTING TIME OF OPERATION AND RELEASE

will vary but slightly from the proper value of about 0.02 second. The test, therefore, gives a good measure of the longer release time which would normally be about 0.1 second.

SOME GENERAL CONSIDERATIONS

As was pointed out above, when an echo suppressor is applied to a telephone circuit, the telephone circuit remains operative in both directions when it is in the normal condition, *i. e.*, when no one is talking. It is only when talking is done over the circuit that the path for transmitting in the reverse direction, which is then useless so far as talking is concerned but which is harmful because it furnishes a path for the echoes, is blocked. The advantages gained by this arrangement are: (1) there is no possibility of cutting off the first part of words owing to the fact that the transmission path actually carrying the speech is unaffected by the switching operations; and (2) if the relays should fail to operate because the voice currents happen to be very weak, the listener at the distant end would still hear the speaker although both he and the talker might also hear some echoes. Weak speech does not, in general, give rise to such serious echoes as does strong speech. Therefore, when the voice currents happen to be so weak that they fail to operate the suppressor, the echoes produced may not be serious.

Now, in order to obtain these advantages it is necessary to face the possibility of "singing," since when no one is talking, the paths for transmission in both directions remain in their normal operative condition. It is evident that if the repeater gains are raised high enough, singing will begin exactly as it would if the circuit contained no echo suppressor. If singing starts in a circuit containing an echo suppressor, the circulating currents will build up until they become strong enough to cause operation of the relay associated with one half or the other of the echo suppressor so that one of the transmission paths will be blocked. This will temporarily stop the singing. It will commence again, however, as soon as the relay falls back to its normal condition. Thus, a chattering condition is produced which, in general, would not be tolerated.

In order to overcome the limitations which may be set on a circuit by the possibility of singing, it is necessary to go back to the old idea of a voice-controlled system in which the transmission is blocked when no one is talking. It is not necessary, however, to block both of the transmission paths since if one path only is blocked, singing evidently cannot occur.

Fig. 7 shows one of the possible arrangements of a voice-operated system in which singing is prevented. It will be seen that this arrangement includes an echo suppressor to which an additional relay D has been added, which keeps the upper transmission path blocked when the circuit is normal, *i. e.*, when no one is talking. Singing is, therefore, not possible when the circuit is normal.

Now, when talking is done at Station W the voice current waves, on arrival at the middle of the circuit, cause operation of the two relays associated with the amplifier-detector W-E. An appreciable length of time is required, of course, to operate relay D. To avoid the possibility of cutting off the initial parts of words during the time before relay D operates, it is desirable to delay the main transmission. What has been called a "delay network" has, therefore, been included as shown in the figure. This delay network may, of course, assume various forms, one of which might be an artificial loaded line or low pass filter. By including such a delay network, the voice currents can be retarded long enough to give the contacts of relay D time to clear the path before the voice currents reach the point in the circuit where the transmission has been blocked.

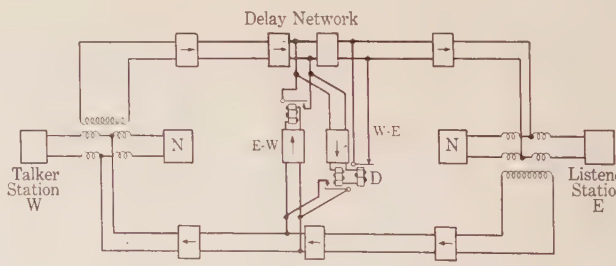


FIG. 7—FOUR-WIRE CIRCUIT WITH VOICE-OPERATED DEVICE ARRANGED TO SUPPRESS ECHOES AND SINGING

In addition to clearing a path for the main transmission in the direction from W to E, the transmission path from E to W is blocked by the operation of the other relay associated with amplifier-detector W-E. The circuit, therefore, has no chance to sing when in the condition for talking from W to E.

When talking is done at Station E, the relay associated with amplifier-detector E-W is operated. This

prevents the echo returning from Station W from operating the relays associated with amplifier-detector W-E. For talking in this direction, therefore, the upper transmission path remains blocked. There is, therefore, no chance for singing, as was also the case for the other conditions.

By adding the delay network, one of the disadvantages of voice-controlled relay systems which keep transmission normally blocked is overcome in large part. This is the clipping off of the first parts of words, the possibility of which was mentioned above.

There remains, however, an important disadvantage in the fact that it is necessary that the voice currents never fail to operate relay D. If they did fail to operate this relay, the listener at Station E would hear nothing. It is necessary, therefore, that the amplifier-detector-relay system W-E be sensitive enough so that the voice currents which traverse the upper path in the four-wire circuit will never fail to cause operation of its relays.

On the other hand, noise currents which traverse the upper path in the four-wire circuit must never cause operation of the relays associated with the amplifier-detector W-E. Such false operation would, of course, prevent transmission over the lower pair of wires from Station E to W and would, therefore, render the four-wire circuit inoperative.

To overcome the singing limitation, it is thus seen that it has been necessary to produce a device which requires greater sensitivity and is, therefore, more seriously affected by noise currents than is a simple echo suppressor. This is in addition to the further complications involved.

Now, in applying simple echo suppressors to long telephone circuits, it is in general not the possibility of singing, but rather, the necessity of avoiding false operation of the relays by noise currents that constitutes the most serious limitation. This is discussed in more detail in what follows. For the present, it is sufficient to note that in the case of most long-distance telephone circuits the method of avoiding singing, which has been described, appears to offer possibilities of limited application only.

Echo Suppressors Applied to Other Types of Telephone Circuits

It will, of course, be understood that in practise a normal commercial telephone circuit is always two-wire at the two ends where connection is made to the subscribers' instruments. The rest of the circuit may be entirely four-wire or it may be all two-wire, or a combination of both. The application of echo suppressors to circuits which are not all four-wire will now be considered.

One important practical case is that where a four-wire circuit is sandwiched in between two two-wire circuits. Such a case is illustrated in Figs. 8 and 9. Fig. 8 shows conditions without an echo suppressor while Fig. 9 shows conditions with an echo suppressor. In both figures, a diagram of the circuit itself is shown in the upper part b, while in the lower part b are shown the paths of the direct transmission and echoes. These transmission paths illustrate the condition when talking is being done from Station W to Station E. In both figures, for simplicity, the first echoes affecting the talker and listener only are shown, echoes of these echoes being ordinarily of little importance.

It will be observed in Fig. 8b, which represents the condition of affairs when no echo suppressor is used, that the listener hears echoes coming from as many as six different paths. The talker hears echoes from three paths. Now compare this with Fig. 9b which represents the condition of affairs when an echo suppressor is employed. It will be observed that all of the echoes which return through the four-wire circuit have been suppressed. Echoes from only two paths now reach the listener, while echoes from only one path now reach the talker. Furthermore, the echoes affecting both talker and listener, which remain when the echo suppressor is

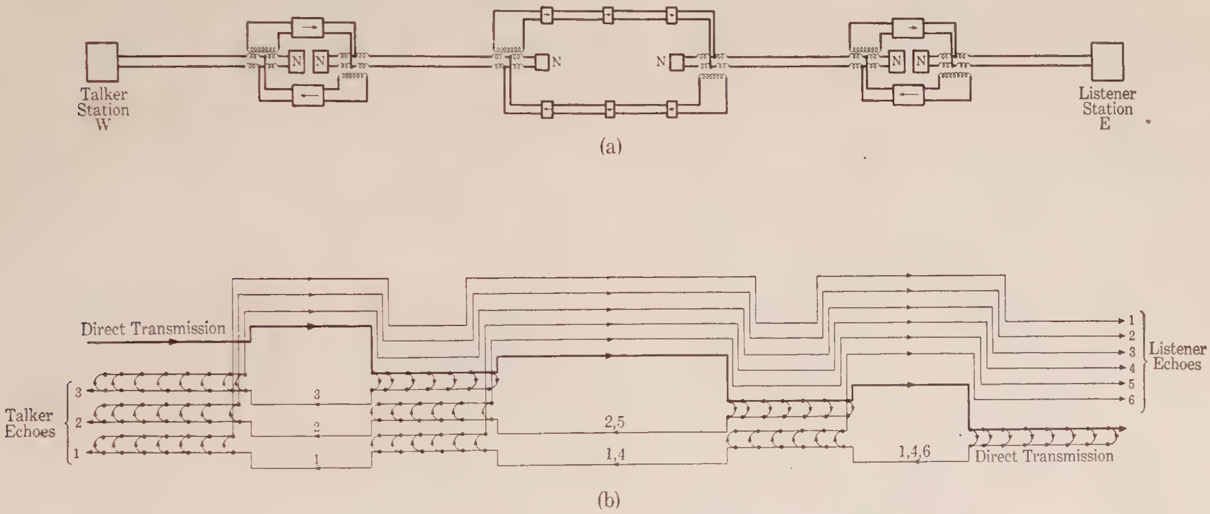


Fig. 8—Echoes in Combination Two-Wire and Four-Wire Circuit

employed, are those whose paths are comparatively short. The echoes whose paths are the longest have been cut off by the action of the echo suppressor. These echoes which travel over the long paths have the greatest lags and are usually most serious. Consequently, cutting these echoes off makes a material improvement possible even though the echoes whose paths are short remain.

In order that an echo suppressor may operate satisfactorily on a circuit, such as the one shown in Fig. 9a, it is necessary that the time required for operation of the relays be short enough so that, if there are any serious echoes returning over short paths, the relays will operate before these reach the suppressor. After operation, the suppressor relays must remain operated until the echoes whose paths are the longest have been suppressed.

In the case of telephone circuits worked entirely on a two-wire basis, echoes may also constitute an important limitation when the circuits are electrically long. On such circuits it is also generally true that the most serious echoes are those whose paths are the longest, namely, those which travel back and forth between points at or near the ends of the circuit. The application of an echo suppressor to one of the repeaters in a two-wire circuit, therefore, offers possible advantages.

If it is imagined that the four-wire circuit shown in Fig. 9a is shortened so that the whole four-wire circuit is located at one point, the two-wire condition would be represented. The time lags which were introduced by the lines comprising the four-wire circuit are now absent. It is possible, however, to introduce delay networks into the two sides of the two-wire repeater to which the echo suppressor has been applied, so as to make it effectively a four-wire circuit, although the two ends are not geographically separated. This would evidently allow the four-wire echo suppressor which has already been described to be applied without modification.

By using somewhat higher speed relays and switching systems, however, it has been found possible in tests which have been made, to obtain satisfactory operation on an all two-wire circuit without introducing devices to produce time lags. This is possible because the important echoes in a two-wire circuit generally lag enough to allow time for relays to operate. Only a few of the echoes return to the suppressor with very small time lags. Some of these can be allowed to pass without causing appreciable impairment, provided they are not strong enough to cause false operation of the relays which block the main transmission path.

Possibilities and Limitations of Echo Suppressors

The curves in Fig. 10 show how, when no echo suppressors are employed, the echo effects limit the extent to which the overall loss of a circuit may be lowered by the application of repeaters.[6] The curves in this figure apply to four-wire circuits of various lengths (without echo suppressors) used to handle terminal business, *i. e.*, connections to subscribers not involving the use of other toll lines in tandem with the four-wire circuit. It is assumed that simple compromise networks giving only a rough degree of simulation of the impedances of the terminal circuits are used. The curves, which are based on experimental data, indicate roughly how the overall volume efficiency must be limited to keep echo effects small enough so that they are not considered disturbing when ordinary telephone conversations are carried on.

Consider, for example, what are the limitations for

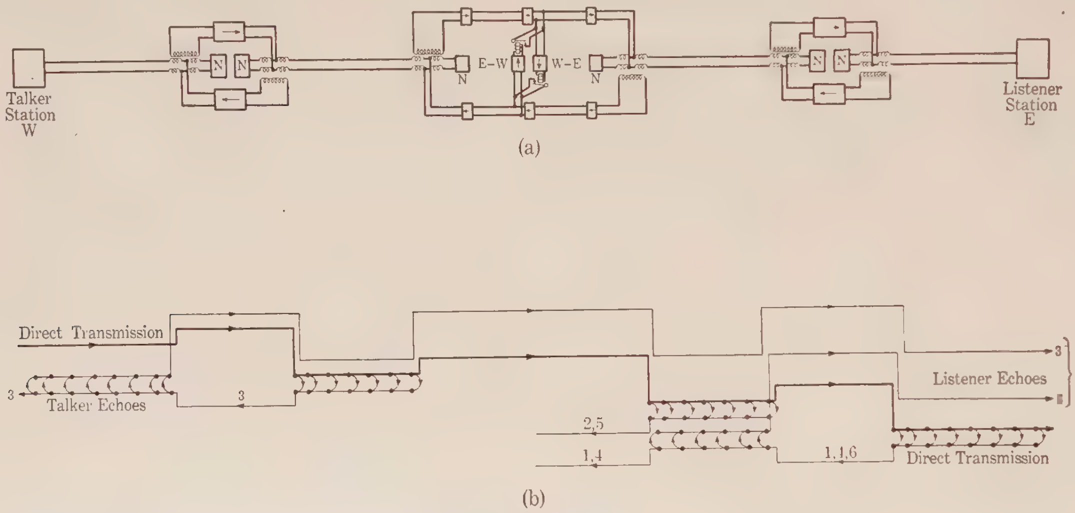


Fig. 9—Echo Suppressor Cutting off Echoes in Combination Two-Wire and Four-Wire Circuit
(a) Combination two-wire and four-wire circuit with echo suppressors
(b) Paths of direct transmission and echoes

6. The ordinates on this figure are in terms of the new "transmission unit" abbreviated "TU," which is defined in a paper entitled "The Transmission Unit, etc." by W. H. Martin, Journal of the A. I. E. E., June 1924. Also in the article entitled "The Transmission Unit" by R. V. L. Hartley, *Electrical Communication*, July 1924.

a circuit 1500 miles (2400 km.) long, with extra light loading. One of the curves which is marked "Talker" shows that in order to keep the echoes which affect the talker sufficiently low, requires that the overall loss in the circuit be made no lower than about 14 TU.[7] The other curve marked "Listener" shows that keeping the echoes which affect the listener within proper limits is a less severe limitation, requiring only that the net loss be made no less than about 7 TU. Singing of a circuit such as this would not ordinarily begin until the loss was reduced to zero or even, perhaps, made less than zero, *i. e.*, an overall gain.

If an echo suppressor were applied to a circuit such as the above, a maximum improvement of the order of 14 TU might be looked for. As a matter of fact, results as good as this have been obtained in tests.

In order to obtain a result as good as this requires, of course, that the echo suppressor be given a sensitive enough adjustment so as to cut off substantially all of the echoes, even when the voice currents are weak. When given such a sensitive adjustment, there will, of course, be a tendency for noise currents to produce false operation. In certain cases, avoiding such false operation may require that the sensitivity of the echo suppressor be reduced to the point where weak voice currents fail to operate the relays. In such cases, results as good as the above will not be obtainable.

In practise, little or no trouble from false operation due to noise within the cable facilities, comprising a four-wire circuit, is experienced. When the connections to the terminals of the four-wire circuit are short, therefore, so that, on these terminal connections, the noise currents are comparatively weak and the voice currents large, it is possible to realize in practise the full theoretical possibilities from an echo suppressor. In other words, it is possible to work a four-wire circuit under these conditions at a very low loss, or even an overall gain.

When the lines connecting the subscribers with the terminals of the four-wire circuit are long, so that the voice currents may be weaker and, perhaps, the noise currents may also be stronger, results as good as this may not be obtainable. However, even in this case, a material improvement can usually be effected by the echo suppressor.

For the condition in which a four-wire circuit is switched to a variety of different circuits at the terminals, it was shown in Fig. 10 that the requirement that echoes should not disturb the talker is more severe, so far as limiting the minimum loss is concerned, than the requirement that echoes should not affect the listener's transmission. It will, of course, be obvious that talkers connected to either terminal of the four-wire circuit through connections involving small transmission losses will hear louder echoes than will talkers connected through circuits having larger losses. In other words, the minimum net loss of a four-wire circuit used in this way is limited by the requirement that the talkers connected through low losses should not receive too much echo. Now, of course, the relays in the echo suppressor will respond most readily to these talkers. Satisfactory operation of the relays for these talkers will, therefore, be secured even though the echo suppressors be given such an adjustment that the relays will not respond to the voice currents from talkers connected to the circuit through a higher loss. Cutting

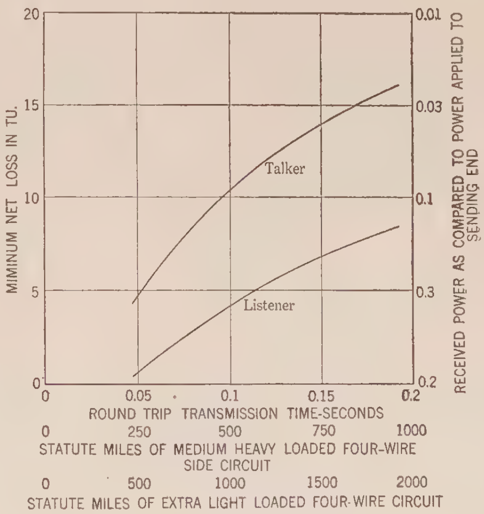


FIG. 10—ECHO LIMITATIONS ON LOSS OF A FOUR-WIRE CIRCUIT

off the talker echoes in the case of the connections involving low losses, therefore, makes it possible to materially lower the loss introduced by the four-wire circuit even though other echoes are not cut off.

In the curves of Fig. 10 it is seen that for a 1500-mile (2400 km.) extra-light loaded circuit the possible improvement which may be secured by cutting off the talker echoes from low loss connections may be as much as 7 TU even though echoes from other connections are not cut off.

In general, for combinations of four-wire and two-wire circuits and for circuits which are all two-wire as well, talker echoes are also more serious than listener echoes provided that the impedance irregularities at intermediate points in the circuit are small, as is usually the case with high grade circuits. Consequently, echo suppressors make it possible to effect improvement in many cases even if the line noise which is present requires reduction of the sensitivity of the echo sup-

7. Due to transmission variations of the different parts comprising long telephone circuits such as these, the overall loss varies to a certain extent with time. In practise, adjustments of circuits in the Bell System Plant are made often enough to keep the variations within about ± 2 or 3 TU. The working net loss must, of course, be made high enough so that echo difficulties will not be encountered when the variations combine in such a way as to give the overall, or net loss, its minimum value. For example, in the case of the 1500-mile (2400 km.) circuit above, if it is assumed that the circuit is limited by echoes to a 14 TU minimum net loss and that it is maintained within limits of variation of ± 3 TU, the working net loss would be 17 ± 3 TU.

pressors to the point where weak voice currents fail to operate the relays. If the line noise requirement does not enter as a limitation, a greater improvement is, of course, possible as is also the case with all four-wire circuits.

CONCLUSION

The echo suppressor, which has been described, offers attractive possibilities in supplementing other methods for obtaining satisfactory transmission over long two-way telephone circuits.

The application of an echo suppressor to a telephone circuit requires no changes in the circuit itself, the echo suppressor being merely attached to the circuit at some convenient point.

For any particular type of circuit, the advantages to be gained by using echo suppressors increase with length. For a given circuit length the advantages to be gained are greater with low-speed than with higher-speed circuits.

Echo suppressors offer the greatest possibility of usefulness on cable circuits, owing to the inherent low-speed and quietness of such circuits. Generally speaking, the application of echo suppressors to cable circuits offers possibilities of effecting savings by allowing the use of heavier weight, lower-speed loadings in place of lighter weight, higher speed loadings, as well as the imposition of less severe requirements as to impedance uniformity of the circuits.

Discussion at Pacific Coast Convention

A COMPLEX QUANTITY SLIDE RULE*

(Du Mond)

Pasadena, Cal., October 15, 1925

L. F. Woodruff (by letter): The complex quantity slide rule described by Mr. Dumond is extremely interesting and ingenious, but since, in his paper, he not only describes the new rule, but gives a synopsis of previous methods of making calculations involving complex quantities, I feel that one omission made in this connection should be pointed out.

On the first page of the paper, in speaking of multiplication

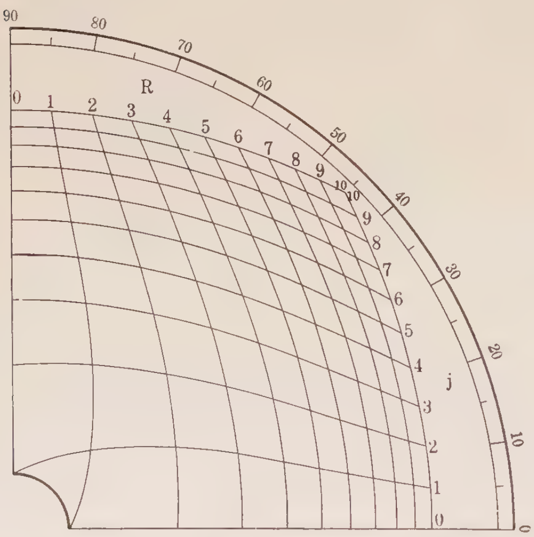


Fig. 1

and division by the modulus-argument method recommended by Kennelly, the statement is made that "each transformation from component form to modulus-argument form *requires* two divisions and looking in tables for the anti-tangent and the sine or cosine of one angle. Each transformation in the reverse direction *requires* looking in tables for the sine and cosine of one angle and two multiplications."

For the past two years there has been available a much shorter method of performing these transformations, in the form of a simple chart[1] (Fig. 1). This chart consists of a set of rectangular coordinates and a set of polar coordinates printed together on the same sheet. Transformation of a complex number from the rectangular form to the polar form is accomplished with one operation, by locating the point representing the number on the chart by means of the known rectangular coordinates, and then reading the polar coordinates corresponding to the same point. The transformation in the reverse direction is accomplished in a similar way. On a chart 11 in. by 17 in., fully as good accuracy can be obtained as with a 10-in. slide-rule, because readings near the origin, where the scales would be crowded together, are avoided by the use of different scales (Fig. 1) so as to cover the whole decimal range at a considerable distance out.

Whenever readings in two dimensions on printed or engraved curves are made, a study of the precision of the result should include a consideration of the effect of uneven shrinkage, which (shrinkage) is considerable, even in the best grades of paper and vellum. With the polar-rectangular conversion chart, the location of a point is finally accomplished by finding its position relative to the lines immediately adjacent. It does not matter how much the rest of the chart may have shrunk or expanded due to humidity and temperature variations and unevenness of the material; the position of the point representing any complex number is perfectly definite. The chart could even be printed on sheet rubber and stretched in any direction without its accuracy being seriously impaired. The accuracy obtainable in the chart is the same as that of the original drawing on the day it was made.

In using the complex-quantity slide rule, the final point representing the result of a two-number multiplication is located by adding graphically two distances measured on different parts of the chart. If there has been an uneven shrinkage, these two distances will not bear the proper relation in size or angle to each other, and a consequent error is introduced into the result. To avoid this it seems that it would be necessary to have the curves printed on some non-shrinking material.

J. W. Du Mond: The extremely clever device of Mr. Woodruff was quite unknown to me hence the omission in my paper of any reference thereto which he quite justly indicates. It is a pleasure to see that others are interested in this problem of facilitating computations with complex numbers.

I have seen a device consisting of a set of rectangular cartesian coordinates provided with a radius arm centered at the origin and bearing a scale of equal parts to give modulus readings. The arm was set at the proper angle by means of a circular scale of angles around the edge of the device. This is, however, open to the objection that shrinkage or distortion of the chart material introduces an error which as Mr. Woodruff points out is completely eliminated in his chart.

I have had no difficulty of this kind in my slide rule because

*A. I. E. E. Journal, Vol. XLIV, February, p. 133.

1. Polar-Rectangular Conversion Chart, John Wiley and Sons, Inc.

although the present form has a chart reproduced on paper paper is mounted by means of an especially chosen cement on a metal backing. I have detected not the slightest shrinkage. A satisfactory method of reproducing these charts directly on a metallic surface is now available and I contemplate utilizing such a method in producing a precision form of Complex Quantity Slide Rule.

D. Journeaux (by letter): Mr. Du Mond's slide rule, excellent in principle, has the disadvantage of involving a parallel motion in a plane; this leads fatally to a bulky construction with possibilities for lost motion. This could be obviated by wrapping chart and indicator around a cylinder, in which case the parallel motion of the indicator would be obtained automatically. It does not seem feasable however to print the chart directly on a cylindrical surface, so that an accurate construction could not be obtained.

A simpler solution is to use polar instead of cartesian coordinates. We know that

$$\log_\epsilon (a + j\,b) = \log_\epsilon \sqrt{a^2 + b^2} + j\,\theta$$

where $\theta = \tan^{-1}(b/a)$. Instead of laying off the real and imaginary parts of the logarithm on rectangular axes, let us choose a reference axis drawn from an origin. Draw a radius making an angle θ with the axis, and lay off on it to a certain scale the length $\log_\epsilon \sqrt{a^2 + b^2}$. The point thus obtained will be representative of $\log (a + j\,b)$; its distance to the origin can be considered as a vector, as it has the same direction as the vector $a + j\,b$.

Using decimal logarithms and plotting lengths from an inner radius $\log K$ instead of from the origin simply change the scale of the chart. The coordinates of a point are then:

$$\rho = \log \sqrt{a^2 + b^2} + \log K = \log K \sqrt{a^2 + b^2}$$

$$\theta = \tan^{-1}(b/a)$$

The equations of real and imaginary curves are obtained by

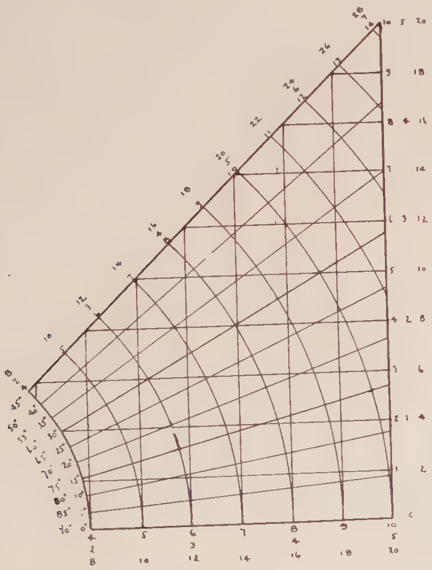


Fig. 2

eliminating b or a between ρ and θ, which gives: $\rho_1 = \log (K\,a/\cos\theta)$ $\quad \rho_2 = \log (K\,b/\sin\theta)$

Fig. 2 shows a ruling obtained by plotting curves for whole values of a and b for the first quadrant, the other quadrants being identical. As the angle of vectors is preserved in their logarithms the quadrant bears an ordinary scale of degrees and, eventually, one of power factor.

The chart, shown in Fig. 3, bears a revolving arm A on the lower side, and on the upper side a slide S which is pivoted on the arm, so that they can be rotated together or separately. The slide bears a logarithmic scale on which $\sqrt{a^2 + b^2}$ is read directly.

For multiplying two vectors we must add their logarithms; the lengths of the components are added radially, and their angles with the axis added, say clockwise. Example: required $(2 + 1\,j)\,(4 + 3\,j)$

(1) The slide being in its neutral position (the middle index on the inner circle) bring both slide and arm to coincide in direction with vector $2 - 1\,j$; push the indicator 1 on point $2 - 1\,j$.

(2) Leaving the arm in its position, bring either index of the slide on point $4 + 3\,j$; the indicator will then be distant from the inner circle by the sum of the lengths of the logarithmic vectors.

(3) Rotating the arm to position $O\,F$ rotates the slide to $O\,G$, the indicator coming on H; angle $F\,O\,G$ is the sum of

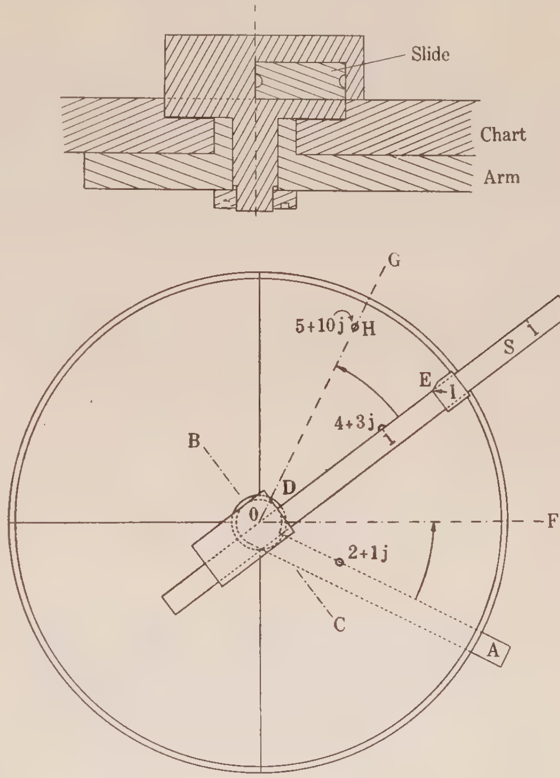


Fig. 3

the angles of the logarithms. $D\,H$ is thus the logarithm of the required vector, and we read the answer $5 + 10\,j$ on the chart.

Running off scale can happen for lengths only, and is taken care of as in an ordinary slide rule. Each operation requires only 3 settings, which are facilitated by the fact that each step can always be visualized.

H. F. Puchstein (by letter): The paper by Jesse W. M. DuMond which was published in the February number provides a neat solution for the problem of the complex quantity slide rule. The usefulness of the arrangement would be increased by adding a set of Naperian log scales at the vertical margins of element A. A set of scales graduated in radians, along both horizontal margins would also be very convenient. Mechanically, greater portability, ruggedness and rigidity would be of advantage.

The arrangement may be used also as an ordinary slide rule for the operations of multiplication, division, powers and roots, logarithms and exponentials. However, when the number of such calculations is limited, slide rules of the ordinary type (when provided with a special set of scales for converting from rectangular to polar coordinates and back) are very acceptable, as with them much tedious work may be avoided. Such rules have been used to a limited extent here and in Europe. A number have been manufactured by Keuffel and Esser in this country

and by John Davis & Son, Derby, England. The conversion from one set of coordinates to the other requires only a single setting of slide and runner for working in either direction. A 20-in. rule in possession of the writer covers 89° 45′ of a quadrant. The operation is particularly simple in those cases where the magnitude or absolute value of a result, but not its quadrature components or its angle, are desired.

There seems to be no reason—though the author of the paper takes the opposite view—why an operator who is able to use the ordinary Mannheim slide should have difficulty in applying the new rule to numerical complex quantity work, at least after a little practise. With this point cared for, almost any intelligent person should be able to obtain correct results quickly, even though he may not understand all the fine points.

A statement of the approximate cost of the new device and the maker's name would be welcome.

Discussion at Midwinter Convention

A STUDY OF DIRECT-CURRENT CORONA IN VARIOUS GASES[1]

(Lee and Kurrelmeyer)

New York, N. Y., February 11, 1925

J. B. Whitehead: In the first studies of corona that were made in our laboratory, one of the questions that came up was whether or not the separate constituents of air played any part in the determination of the laws by which the corona was formed. And the original question which Dr. Lee started out to investigate was whether the oxygen of the air or the nitrogen of the air would show any remarkably different properties as regards breakdown.

For the engineer there are, then, two matters in this paper which I think are of immediate interest. The first is the answer to the question that I have already indicated, namely: that the properties of oxygen and nitrogen are not markedly different as regards the formation of corona. If they had been different, it would have been very easy to imagine conditions under which advantage might have been taken of any such differences.

The other matter has to do with the values of voltage at which corona forms around wires in the range in which we use high-voltage conductors; that is to say, pressures that are not greatly different from atmospheric pressure.

A matter of interest to me directly is the fact that Dr. Lee and Mr. Kurrelmeyer have linked up the behavior of the several gases investigated at low pressures with that at high pressures. Those who remember my corona-voltmeter paper will recall that there the pressure was carried down to about 30 cm. only. We stopped at 30 cm. I think largely because it became increasingly difficult to make the corona tube tight at lower pressures. Dr. Lee has picked up the air curve below 30 cm. and carried it on well down below 1 cm. He has found that his curves link up with those brought out by Mr. Isshiki and myself, but he shows also that the empirical law which we show for the corona-voltmeter does not hold in his low pressures, that is, in the range of very low pressures.

Turning to the physical discussions in the paper, Dr. Lee has indicated the main results of their investigation. I regard it as a very distinct contribution to the field of physical investigation in the matter of the ionization of gases. The authors have shown very clearly indeed the difficulties of coordinating their results with the only important theory we have, namely: the theory of ionization by collision. And I feel quite sure that this paper will suggest to a number of physicists who are interested in the phenomena of the ionization of gases, the importance of carrying further the study of these interesting questions.

F. W. Peek, Jr.: In establishing the visual corona relation for variation of radius of wire, temperature and pressure, my experiments were carried down to fairly low pressures. The relation holds very well down to 5 cm. This means, of course, that the transmission-line range is more than covered by the equation.

For a given conductor the visual corona gradient decreases with decreasing pressure until a minimum gradient is reached. The gradient then increases with decreasing pressure. At the very low pressures the molecular separation may be fairly large compared to the diameter of the outer tube. A different phenomena thus occurs and the above relation could not be expected to hold.

The interesting part of the paper is that a number of different gases have been investigated. So far the data are limited in that the authors have only used one size of conductor. I hope that the investigation will be carried over a greater pressure range and that different sizes of conductors will be investigated.

Note. See also discussion of this subject by Joseph Slepian, page 630.

F. W. Lee: I can say only this in regard to Dr. Slepian's discussion: that so far as using the value E over P as an indication of the energy given in the mean free path of a gas electron is concerned, that was given only with the idea that the values so used came within the range of magnitude that had been worked out at pressures very, very low, such as are used in vacuum tubes. In other words, the phenomenon that we are observing is that the observed results checked in the order of magnitude, although not within the absolute value. The agitation velocity under a charged field, where the transfer of energy goes, you might say, from the very great velocity of the electron and imparts the velocity to the molecules, will give other mean free paths and other distributions of velocity from those given with gas under normal conditions, which I used as the indication of the results in the beginning of the paper.

With regard to Mr. Peek's remarks, I will say that the work is being extended as fast as we can extend it, with the limiting conditions under which we are working and with the material available.

1. A. I. E. E. Journal, Vol. XLIV, January, p. 16.

DIELECTRIC PROPERTIES OF FIBROUS INSULATION AS AFFECTED BY REPEATED VOLTAGE APPLICATION[1]

(Clark)

New York, N. Y., February 11, 1925

J. B. Whitehead: I think the striking result of this paper is the indication that sometimes insulation that has been strained will recover and sometimes it will not. It is easy, from our present knowledge of the properties of insulation, to see how both of those things may occur. Composite insulation is distinguished principally by the property of dielectric absorption, sometimes called viscosity, sometimes spoken of as the property of having residual charge.

If you take a dielectric showing residual charge or absorption and carry it up in temperature, you will find that the absorption will merge into a pure conductivity at high temperatures. If the dielectric is sufficiently homogeneous and uniform and controlled, it may be brought down again from those regions of high temperature, and show all of its original properties. In other words, absorption generally merges into conductivity at high temperatures. It is easy to see, then, how a non-homogeneous dielectric may have this property in excess or preponderance over other properties, and so recover.

The case of non-recovery it seems to me is also equally easy to

1. A. I. E. E. Journal, Vol. XLIV, January, p. 3.

understand. We very rarely have homogeneous composite dielectrics. Particularly in the case of fibrous dielectrics, we have a variety of other phenomena entering. We have the question of moisture. We also have undoubtedly the phenomena of electrolytic conduction. We have fibers present. We have every possible suggestion of localized structural paths. It is quite easy to see that if we apply voltage to such a structure for a limited time, it is possible that electrolytic conduction, to fix our attention on only one of them, may take place along certain limited paths to their ultimate destruction. This electrolytic conduction can be a cause of local heating; it can be a cause of the disintegration of the structure of the material itself, without resulting in breakdown.

The conditions of experiment in Mr. Clark's observations were not sufficiently controlled, I think, really to offer us any definite information on the subject of Dr. Wagner's hypothesis. I think we have assumed a wider field for the application of this hypothesis than is warranted. I believe that if we talked to Dr. Wagner himself he would immediately limit his proposal to the range in which the absorptive properties of dielectrics are merging into those of conduction.

H. W. Fisher: Mr. Clark is to be congratulated on his ability to prepare a number of samples in the tests of which he gets such remarkably consistent results. I know from experience that this is quite a difficult undertaking.

I was interested in the fact that some of the samples showed that the material was injured electrically by the application of very high voltages. I have often had reason for believing that the regular run of cables may be permanently injured if too high test voltages are applied. Cables, no matter how well saturated, are changed in their structure, due to the winding and rewinding in the lead covering and installation processes, whereas, the samples prepared by Mr. Clark, were not subjected to mechanical stress, after being prepared for test.

A number of years ago, we had a customer who never specified any high-voltage tests on cables purchased from us. We always made a routine factory test on these cables of at least double working voltage. For years and years no burn-outs were ever reported on cables furnished this customer and our vice-president, Mr. W. A. Conner (who was well known by many of the older members of the A. I. E. E.) often used to remark that the operators who did not specify very high voltage tests seemed to have the least operating troubles so far as the cables were concerned.

I shall cite the case of an experimental cable made about 15 years ago which, when repeatedly tested, did not show this deteriorating effect by the application of high voltages. In the construction of the cable, an extremely viscous and elastic compound was used. The cable withstood voltage tests which were very remarkable at that time and which, in fact, were higher than any required at the present time. Still more remarkable was the fact that although the cable was broken down, a great many times, the fault removed and new tests made, the breakdown tests were within 1000 or 2000 volts of each other every time, the tests being in the neighborhood of 50,000 volts.

Good as this cable appears to be, it would not have withstood the N. E. L. A. bending tests at minus 10 deg. cent. The compound used was a vegetable material, no mineral compound entering into its composition. This does not necessarily mean that cables made with vegetable-base compound do not deteriorate so much from high-voltage tests, as those made with mineral-base compound.

M. F. Skinker: In the synopsis of his paper, Mr. Clark mentions the pyroelectric theory of breakdown as developed by Steinmetz, Wagner, and others. The possibilities offered by thermal theories have been admirably discussed by Dr. E. Dreyfus in Bulletins No. 7 and No. 12 of the *Schweitz Elektrotechnischer Verein*, 1924. His paper deserves to be carefully studied by all who are interested in problems of this nature, particularly from a designer's standpoint. Mr. Clark states that the transformation to thermal energy proceeds "at a rate proportional to the stress applied." Obviously, it should be "at a rate proportional to the *square* of the stress applied."

In order that the original properties of the dielectric after stress might be restored, it must be assumed that no electrical strain or chemical action has taken place until the stress actually reaches the point of failure. Since none of our dielectrics are perfectly homogeneous, we would expect partial deterioration of stresses even far below the average breakdown value, the partial deterioration being nothing but the premature breakdown of weak spots or filaments. It is on the presence of such weak filaments that Wagner builds his thermal breakdown theory, and it has very justly been criticized on account of the arbitrary assumption that must be made relative to their size and physical constants.

"Rapidly applied 60-cycle voltage" is not a definite reproducible quantity unless the exact phase of the voltage is known at the time of its application. There may well be transients and reflections in the dielectric under certain conditions. Therefore, when studying the laws governing breakdown under prolonged stress, the voltage should never be applied abruptly but always should be allowed to start from zero. The time to reach full value need be only a fraction of a second, provided it is large compared to the time taken for an electro-magnetic wave to cross the dielectric.

Further, before taking fifteen minutes as an arbitrary time limit, it would be well to investigate thoroughly the effect of long-time application of lower voltages. If we are making tests

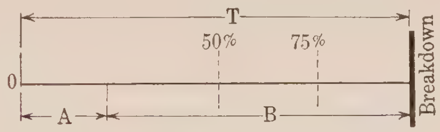


FIG. 1

in the light of the pyroelectric theory, we must take into account all the thermal properties of the system we are studying. When we get a failure due to a continuously applied voltage of several minutes duration, it may be satisfactory to neglect the specific heat of the insulation and that of the electrodes, but certainly when we are considering intermittent application of voltage we must take this into account.

It is possible to make a very simple picture of the reason for the apparent discrepancy in the law $R \times T = K$. When we apply a voltage that will cause a breakdown in an interval, some time will be spent in heating up the system before the critical point is reached. In Fig. 1 let the total interval be T, B the time to reach the danger zone of breakdown and A the rest of the interval.

Now each time we apply the same voltage for a shorter interval (that is, varisous percentages of the time T as indicated in Mr. Clark's paper) we see the quantity B enters in and should be corrected for. By making simple calculations, considering each of the indicated points on the graph, a mean value of B can be found. For instance, in Fig. 15, B came out 10.2 per cent of the continuous time to puncture; in Fig. 17, 15 per cent; in Fig. 9, 33 per cent, etc.

Now obviously, if we only apply the stress for these percentages of the time, we should not expect to get a breakdown of the insulation. This is faithfully indicated in the curves by the fact that they apparently have asymptotes at these values. If the equation were $R \times T = K$ the horizontal axis should be the asymptote.

The thermal conditions do not permit definite calculations but I cannot see anything in the data that definitely disproves the pyroelectric theory, but they seem to substantiate it.

G. E. Luke: These tests show without doubt that fibrous insulation has the characteristic which may be called "dielectric fatigue." The author stated that this fatigue or deterioration is permanent under the conditions given except for the case when a rapidly applied test is made after a rest period following a previous voltage application. In this instance the material breaks down at approximately the same value with or without the previous application of stress.

The above author's conclusion will evidently hold true only under the particular conditions tested, since Rayner[2] found that a prevoltage application followed by a rest will materially change the rapidly applied breakdown. Thus Rayner found that a certain oiled cloth will break down in 81 min. on the application of 5500 volts on a green sample, and 6500 volts will break down in about 29 min. on a similar sample. Now when the material is given a pre-voltage test of 5500 volts for 40.5 min. (one-half the breakdown time) and allowed to recover over night, its breakdown time on the application of 6500 volts is only 0.8 sec. instead of 29 min. as found on the green material.

The intermittent application of voltage as shown on Figs. 9 to 18 show that the insulation has deteriorated and would not recover since many of the tests were made with 60 min. between tests. The author says, "with mica or with fibrous materials heated in oil between voltage applications the effect of intermittently applied stress is diminished and an increase in dielectric life is observed." Complete data for such a conclusion could not be found in the paper since the only tests given for mica were on Fig. 18 taken at room temperature. Also due to the erratic variations in the test points it is believed that no definite conclusions can be drawn from the slight differences of curves on Figs. 16 and 17.

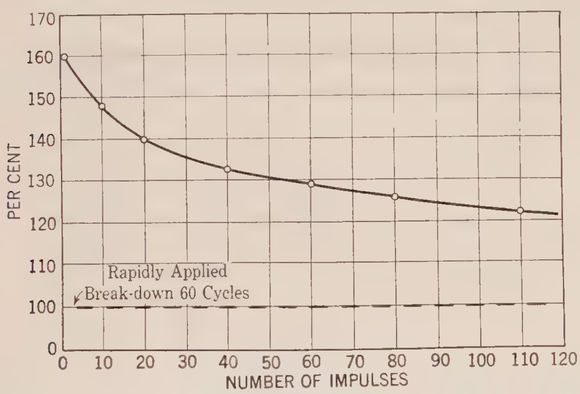


Fig. 2

In this paper the repeated voltage applications were made with 60-cycle voltage over periods of time of about a minute in order of magnitude, while the time of voltage strain in service due to lightning surges would be measured in microseconds. It will probably be of interest to show the effects of repeated voltage impulses of such short-time waves. Fig. 2 shown here gives the average results of a great number of tests made in the Westinghouse Research Laboratory. The material tested was 0.015-inch sheet fullerboard under oil. The rapidly applied breakdown strength (5 to 10 sec.) with 60-cycle voltage is called 100 per cent. The curve gives the dielectric strength compared to the 60-cycle strength for various number of impulses. The impulse was obtained by charging a condenser until the voltage discharged through a spark gap. The voltage impulse given to the insulation could be controlled by the constants of the circuit. The total time of the damped single wave of impulse for the tests shown was 4.0×10^{-6} sec. so that on breakdown with one impulse the time of the voltage application was about 2.0×10^{-6} sec. The time interval between impulses was about 5 sec., hence the energy was too small to give any noticeable heating. With 500 to 1000 impulses the voltage breakdown strength was about the same as the 60-cycle breakdown (rapidly applied). The fact that this strength with an impulse of 2×10^{-6} sec. is only 60 per cent higher than the 60-cycle, 5 to 10 seconds, breakdown seems remarkable. Such facts are also confirmed by Peek[3] of the General Electric Company.

This discussion leads up to the questions, what causes the "dielectric fatigue" such as described in Clark's paper, and in general, what causes insulation failure? It is known that under certain conditions insulation may fail due to accumulative heating of small fibers in accordance with the Wagner's pyroelectric theory. This may account for the recovery in insulation strength with a 2-minute rest as shown in Fig. 2 of the paper. In this case the localized heating was non-sufficient to change the material. The results shown with the repeated voltage applications in the author's Figs. 8 to 18 show a deterioration in the insulation, since the time interval between tests was generally sufficient to remove such localized heating, it is evident that some of the insulation fibers were permanently injured by each voltage application. However, on the basis of this pyroelectric theory one would naturally expect mica to stand up much better than fibrous insulation, but the curve on mica, Fig. 18, does not differ much from similar curves on fibrous materials. The data given on Fig. 2 with 4-microsecond impulses can hardly be explained on the basis of the pyroelectric theory since the time of application is so infinitesimal compared to the time used in the other tests. It appears that the fibrous insulation might have a critical voltage similar to the breakdown voltage of air. Such a breakdown might be explained on the basis of corona or excessive internal ionization. Whether dielectrics have free ions and can form corona due to critical voltage stresses is problematical and little information is available. The difficulties of researches along this line are due to the heterogeneous composition of the common dielectrics.

Corona may form in built-up insulation due to occluded air pockets, the results of which may form a chemical action on the insulation. Such action would cause permanent deterioration. This also does not explain the tests shown, since many of the samples were vacuum-dried and impregnated in oil. Also mica which deteriorated about as fast as the fibrous materials, is especially resistant to this chemical action.

Anderson[4] has shown that if a powerful condenser is discharged through a small wire the wire can be completely exploded into a gaseous residue. The time of the discharge being only a few microseconds, the heating effect is too small even to scorch the cotton covering on the wire. The breakdown of a dielectric sheet with such a voltage impulse seems to be of the same nature, as a small thread through the material may be completely removed without showing signs of burning. The explanation of such a phenomenon does not seem possible on the basis of electrostatic repulsion nor on the basis of electromagnetic forces due to the displacement current; it is a complete disassociation of the molecular structure.

Joseph Slepian: The three papers on *Study of Direct-Current Corona in Various Gases, Effect of Repeated Voltage Application on Fibrous Insulation and Corona in Oils* illustrate two kinds of cumulative effects in insulation, a space-cumulative effect, and a time-cumulative effect. The space-cumulative effect arises from the fact that contiguous layers of insulation mutually influence one another so that the conductivity of one layer is communicated to the next layer, with a resultant cumulative mutual weakening of these layers under stress.

For example, 1 cm. of air will break down at 30,000 volts per

2. "High Voltage Tests and Energy Losses in Insulating Materials," by E. H. Rayner, National Physical Lab. 1913.

3. "The Effect of Transient Voltages on Dielectrics," by F. W. Peek, Jr. Journal A. I. E. E., 1915.

4. "Spectrum of Electrically Exploded Wires," by J. A. Anderson. *Astrophysics*, January, 1920.

cm. gradient, but 0.001 cm. of air withstands 300,000 volts per cm. gradient. Thus, if a thousand layers of air, each 0.001 cm. thick, are placed next to one another, they will exert a mutual cumulative effect upon one another in such a manner that each layer is respectively weakened by effects coming from other layers, so that the breakdown gradient is reduced from 300,000 volts per cm. to 30,000 volts per cm.

Similar results are obtained with liquid dielectrics, or solid dielectrics. In Peek's "High Voltage Engineering," I find in one table that 1 cm. of a certain grade of oil would break down at 166,000 volts per cm., whereas ⅛ cm. of that same oil was able to withstand 364,000 volts per cm., a gradient more than twice as great. Evidently by taking eight of these ⅛-cm. layers and building up a whole centimeter, the mutual cumulative effect of these layers upon each other was such as to reduce the strength of each individual layer.

In solid insulation, the breakdown voltage is not proportional to the thickness of the insulation, but to some fractional power of the thickness, which again demonstrates a space-cumulative effect.

The mechanism of this cumulative effect is probably to be found in the nature of conduction in dielectrics. The conductivity is undoubtedly due to charged particles capable of motion in the material, and the effect of high voltage somehow is to increase the number of these charged particles. With insulation of any appreciable thickness, the conductivity produced by the high-voltage gradient at any one portion of the insulation may be communicated by direct motion of these particles to other portions, and vice versa, so that there results a cumulative effect of one layer upon the other, the increase in conductivity of one portion stimulating the increase of conductivity in other portions.

In the paper by Crago and Hodnette, this mutual influence of portions of dielectrics upon each other is very clearly shown. Only the oil next to the wire was very highly stressed, but Crago and Hodnette observe and actually measure the decrease in dielectric strength and increase in conductivity produced at points rather remote in the oil. That this effect exists is not new, but I don't remember seeing any definite quantitative information with respect to this for commercial transformer oil under ordinary operating conditions, so that the results they give are of very considerable interest and in some respects of considerable value.

The other type of effect with which Mr. Clark is principally concerned is the time-cumulative effect. We consider now contiguous elements of time. An element of time in which the insulation is highly stressed will influence the conductivity or dielectric strength of the insulation in the following period of time, usually causing the conductivity to increase and dielectric strength to decrease; a period of low stress may also influence the period immediately following, usually by causing the conductivity to decrease and the dielectric strength to increase.

This time-cumulative effect is not limited to solid insulation. In the case of gaseous insulation, it is a phenomenon long known, but described ordinarily as spark lag. High voltage may be applied to a spark gap for a very brief time, with only a very small current flow. If the voltage is kept on, this current flow increases at a very rapid but nevertheless finite rate, until full breakdown takes place. Complete breakdown of a sphere gap requires a few hundreths of a microsecond. The successive moments of stress all contribute to the breakdown.

That a period of low stress tends to improve the dielectric properties of air is well known to the operating man. When an insulator flashes over, and the circuit breaker trips out, he closes it in again with the reasonable expectation that the rest given to the broken-down air will have permitted it completely to recover its dielectric properties.

In oil we also have this effect and Crago and Hodnette give quantitative measurements on the time involved. In their curves they show the time it takes for abnormal conductivity to disappear during a period of low stress.

Of course, as one would expect, in the case of the gaseous insulation, the time-cumulative effect is exceedingly rapid, in the case of liquids much less rapid, and in the case of solids still less rapid.

The mechanism of this time-cumulative effect is fairly well understood for gases. A high enough gradient in air will cause the production of charged particles which can serve as carriers of current, but the rate at which new charged particles are produced is also proportional to the number of charged particles present. Thus the number of new charged particles produced in any time interval depends on the number of particles left by the preceding time interval. The theory of ionization by collision gives a very vivid picture of this process.

In liquids and solids in all probability, similar phenomena take place, but in these cases another effect may contribute to the time-cumulative effect, namely, the heating of the insulation with resulting increase in conductivity. This aspect has been particularly stressed by K. W. Wagner in his pyroelectric theory of insulation breakdown. There is no doubt that in very many cases breakdown is caused by cumulative heating, but some of the data presented here today, and data given by others, notably Rogowski in the *Archiv der Elektrotechik* show that the pyroelectric theory does not adequately explain dielectric breakdown. If the breakdown voltage for various insulating materials is calculated according to Wagner's theory, using the electrical conductivity and thermal constants of the material as ordinarily measured, values are obtained very much larger than those obtained by experiment.

With all these effects in mind, there is a point that I would like to bring out very emphatically, and that is that we have no right to speak of a breakdown gradient characterizing a dielectric material.

The idea of a definite breakdown gradient probably rose out of the analogy with failure under mechanical stress. Any particular point of a body will yield mechanically if and only if the mechanical stress at that point reaches a certain definite value characteristic of the material, and independent of the stresses which may exist elsewhere. How natural to suppose that under electric stress also, the failure of any point in a body is determined entirely by the electric stress at that point. But it isn't true! There is no definite breakdown gradient. Because of the cumulative space effect, and the cumulative time effect, the gradient which may exist in any dielectric system when breakdown occurs will have no simple relation to the nature of that dielectric. This idea of there being a definite breakdown gradient characterizing materials is one that has colored our engineering thought on insulation for a long time: I believe it has done a great deal of harm and it is time that it should be discarded.

Only a few years ago I remember there was a very considerable discussion as to whether the breakdown in cables could be determined by the maximum stress in the cable or the minimum stress. In the light of the phenomenon that has been described in these papers such discussions seem to be meaningless. Even for a perfectly definite reproducible material, the gradient at breakdown will not be the same for this material with different thicknesses and with different arrangements of conductors. There is no reason why it should be, according to the theory of breakdown in dielectrics and in the light of these effects that have been described.

Lee and Kurrelmeyer, in their paper, take some time to discuss the adequacy of the theory of ionization by collision in explaining their results, but I do not believe that this theory was quite fairly treated in their discussion and some of the conclusions which they say will follow from the theory of ionization by collision do not seem to me to be entirely warranted.

One of the conclusions which they draw from this theory

is that E divided by P should be a constant for any particular gas. E is the gradient at the wire surface when corona begins and P, the pressure of the gas used. They state that E/P is proportional to E times the mean free path, and therefore is proportional to the energy acquired by an ion moving through the mean free path, and that this energy should determine whether ionization by collision takes place or not.

If this were true, then the idea that there is a characteristic breakdown gradient would be justified, because then the breakdown would be determined entirely by whether or not a certain definite stress had been reached. Now I have been trying to bring out the point that breakdown is not determined only by some definite stress being reached.

The reason why this conclusion of Lee and Kurrelmeyer is not warranted is that the mean free path is not a real physical quantity. The mean free path in a gas is only a statistical quantity, an average quantity. If a large number of actual free paths are considered, it will be found that there are many very short ones, and a few very long ones. The average of them all is the mean free path, but there are always a few with much greater lengths. Ionization by collision will take place even at very low gradients due to these few very long free paths. Thus ionization by collision does not set in at a definite gradient, but it occurs weakly for small gradients and then more and more strongly as the gradients increase.

What is it that sets in at some definite voltage on the system? What sets in is an instability due to the mutual action of various portions of the ionized gas upon each other. Given a gas between definite electrodes ionization by collision will occur at all voltages; there is, however, a certain voltage where the ionization produced in one portion of the gas so multiplies the ionization in the next portion, that working back on the first portion, there is produced a cumulative instability and a breakdown.

The proper relation which should be expected, and which I venture to predict will be fairly accurately confirmed, is not that E/P shall be a constant, but another relation given by Paschen's law. Paschen's law connects the breakdown voltage for plane electrodes, the electrode separation and the pressure. Paschen's law has been generalized by Townsend to cover the case of any shape of electrode, and Townsend's generalization may be put in this way: if P is varied, and if at the same time the dimensions of the electrodes are varied so as to keep the ratio of the mean free path to the dimensions of the electrodes constant, then E/P will be constant. Hence in this case E/P will be a constant if the dimensions (here the radius of the wire) multiplied by the pressure is kept constant. It is only if the wire radius is varied in this manner that E/P will be constant, according to the theory of ionization by collision.

It is rather interesting to note that the formula of Peek is consistent with this condition.

D. Bratt: I believe that it is justifiable in this connection to emphasize some general consequences of the purely thermal idea of breakdown that seem to be less realized than warranted by their importance, and which have a direct bearing on the subject of Mr. Clark's paper.

First, it should be noted that breakdown is caused by excessive current, and that voltage as such has nothing whatsoever to do with the so-called "pyroelectric theory." We must therefore carefully distinguish between instantaneous breakdown and thermal breakdown, the former being caused probably by some sort of molecular yielding due to purely Newtonian forces. It does not appear that Mr. Clark makes this distinction in his voltage applications.

The development of heat in a plate, subjected to voltage, not only leads to higher temperatures in the interior, but also to a re-distribution of voltage gradient, even though there be no internal free charges by assumption.

The relation between current density and temperature should therefore be determined, and the subsequent numerical evaluation of the obtained formulas should be based on tests of dielectric losses as a function of current density and temperature.

The maximum stable current density can then be determined. We will get an expression of the following form:

$$\Delta_{max} = \frac{1.84}{d} \sqrt{\frac{\lambda}{\rho_0 k}}$$

where d = thickness of the plate
λ = thermal conductivity
ρ_0 = initial value of dielectric loss per cm³
k = the logarithmic increment of temperature
and the dielectric loss has been assumed to obey the law

$$\rho = \rho_0 \Delta^2 \epsilon^{k \odot} \frac{\text{watts}}{\text{cm}^3}$$

The corresponding temperature rise inside the plate

$$\theta_{max} = \frac{1.10}{k}$$

From these equations we obtain the maximum strength

$$E_{max} = \frac{1.84}{f} \sqrt{\frac{\lambda}{\rho_0 k \mu^2}}$$

Where f = frequency, u = the average dielectric constant estimated from the known temperature distribution inside the plate and previous d-c. tests of dielectric constant as a function of temperature.

We have assumed here the simplest possible case, when the surface temperature of the plate is taken as reference level. This temperature is generally not known; therefore, the heat dissipation from the electrodes must be taken into account.

It should be carefully noted that E_{max} is independent at the plate thickness d, assuming as we have done, a homogeneous dielectric.

The strength of the insulation is, therefore, determined by neither $\rho_0 \lambda \mu$ or k alone, but on the factor $q = \dfrac{A}{\rho_0 k \mu^2}$.

During a prolonged stress, the strength of most materials has been found to decrease. Thus, were it possible to keep our plate under maximum voltage, we would have to decrease this voltage gradually in order to prevent breakdown.

It is a very reasonable assumption that the cause for this decrease in strength, aside from the natural aging of the insulation, is nothing but the applied voltage itself, or still better, the energy developed. Any structural change in a material requires energy.

For some time, T_0 onward, the change in q becomes very gradual, and we could write, tentatively

$$q = q_0 - a \int_{T_0}^{T} E_{max}^2 \, d\, t$$

differentiating

$$\frac{d\,q}{d\,T} = -\,a\,E_{max}^2$$

and according to the expressions found for E_{max}

$$\frac{d\,q}{d\,T} = -\,A\,q$$

(where A is a constant)

Integrating, then, gives $q = q_0\, \epsilon^{-A\,(T - T_0)}$

E_{max} will, therefore, according to the hypothesis made, asymptotically approach zero, and this result indicates in my opinion very definitely the danger of prolonged stresses near the breakdown point.

Everything leads us to believe that this change in strength is an irreversible process. Therefore, if the material has been once so stressed, and the voltage then removed, nothing should lead us to expect a return to the initial state. This does not,

of course, apply to moderate stresses, which have been found to improve the strength in many cases, usually due to some drying out process.

When studying the effect of prolonged or intermittent stresses on a solid dielectric, we believe it would be profitable to work along some hypothesis similar to the above. If correctly understood, the pyroelectric theory might yield results of great suggestiveness, and in this case, as always, a theoretical analysis prior to any experimental work offers the best possible guarantee against excessive laboratory expenses and results that have no general applicability.

Incidentally, I might add that for a crucial test on the pyroelectric theory as such, direct current ought to be used instead of alternating current. This would eliminate internal charges and some other unknown factors. If this theory failed for direct current, it would certainly not be expected to be valid for alternating current.

A. C. Crago: The most variable quantity which I have run into in engineering work has been the time of breakdown of dielectrics. So far as I know, it is the most variable quantity which we try to assign a definite value. We see in Mr. Clark's paper that the time of breakdown is a decidedly variable quantity.

I shall confine my discussion to the group of curves numbered 8 to 18 in Mr. Clark's paper. I shall review briefly the conclusions or the results which Mr. Clark has obtained from these eleven curves as I understand them.

First, that with oil-impregnated or oil-immersed fibrous materials, the cumulative effect of an intermittently applied voltage is directly additive; second, that with varnished materials, the cumulative effect is not additive; third, that the cumulative effect is not directly additive in any case for shorter times of application than 30 to 15 per cent of the 100 per cent time.

Using these results as evidence, Mr. Clark's general conclusion is, I believe, that there is some permanent deteriorating effect on the insulation in all cases due to this voltage application which is not removed by the rest period between tests.

After a rather detailed study of the data presented in Figs. 8 to 18, I believe that although the above conclusion may be correct, it is not warranted on the basis of the data presented, because of the wide variation in the time required for breakdown with a voltage continuously applied.

The following table presents the range of values obtained in determining the "100 per cent" points of the group of curves:

Fig. No.	Lowest	Highest	Ratio
8	0.40	1.60	4–1
9	0.40	1.7	4.2–1
10	0.50	1.55	3.1–1
10	0.35	2.0	5.7–1
11	0.35	1.8	5.1–1
13	0.35	1.75	5.0–1
14	0.25	2.0	8–1
15	0.5	1.5	3–1
16	0.2	1.85	9.2–1
17	0.2	1.9	9.5–1
18	0.2	2.5	12.5–1
Average Range 6.3 to 1			

Obviously, if we use the average of five or six values which vary over such a wide range, the mean value is subject to a rather large variation. A calculation with an average variation of 50 per cent from the mean, (which is found in some cases) shows that the probable error of this average is over 20 per cent.

However, although the reasoning given above will account for errors in the values of results, it presents no evidence to show that the relation $R\ T = K$ is not necessarily due to a permanent weakening which lasts over the rest period.

I shall now present evidence for this. First, let me say that not all observers have found the effect Mr. Clark gives. E. H. Rayner gives the following table for two thicknesses of Number 12 cloth immersed in oil, which it seems is comparable with the data of Clark:

Recovery in varying periods of rest after application of 9000 volts for 1 minute (breakdown at 9000 volts—1½ to 2 minutes)

Period to rest	Time to break at 11,000 volts
0	2.6 seconds
1 min.	9.5 seconds
2 min.	11.9 seconds
fresh material	12.0 seconds

It will be seen that after a rest period of two minutes, the insulation stood the test voltage for practically as long as unstressed material. I cannot tell you how these results were obtained or the laboratory conditions under which they were obtained, but give them to you as a result which was published by E. H. Rayner under the title of "High Voltage Tests and Energy Losses in Insulating Materials" in the *Proceedings* of the I. E. E. of 1912, Volume 49, page 214.

Instead of assuming that there is a premanent effect on the insulations used in Mr. Clark's tests due to high voltage stress, let us assume that when voltage is removed, the area under test returns, not to its original condition or to a poorer condition, but to the condition of a random point. That is, let us assume that it has the same chance to break down in 10 sec. or 20 or 30, sec., as though we had chosen a fresh point on the insulation. What will be the result?

Let us analyze one of Mr. Clark's curves on this basis, taking as an example Fig. 8.

Referring to this curve, we find, that there is one breakdown obtained at about 40 per cent of the time referred to as the mean value or the 100 per cent time, and that five tests have been used to obtain this average. This means that if we choose new points on the dielectric and apply voltage, approximately one time in five breakdown will occur in 40 per cent of the 100 per cent time. Of course, that cannot be a very definite quantity, because only five points are given here.

Also, if we apply the voltage for 40 per cent of the 100 per cent time, remove it, move the electrodes, and apply it again for the 40 per cent time, a breakdown will occur one time in five.

Let us see now what happens when we apply voltage for periods of 40 per cent of the 100 per cent time and do not move the electrodes. Referring again to Fig. 8, we come down to the 40 per cent time and across till we strike the curve, and we find that that corresponds to a number of applications of 5½, which I would consider an excellent check. That is, this insulation, whatever the cause of the variation, has acted in such a way that the curve could be explained on the basis which I have stated and will state again: that an insulation stressed under the conditions given does not return to its original condition, nor to a poorer condition, but to the condition of a random point.

I have analyzed the eleven curves given, attempting to explain their shape on this basis, and I find that nine of the eleven give a reasonably close check and that two of these nine are more than explained by this assumption.

After reading Mr. Clark's paper I made some tests with oil, using a standard Westinghouse test cup, which consists of two square-edged cylindrical electrodes 1 in. in diameter, spaced 0.1 in. apart. The oil was stirred after each application of voltage. The procedure described by Mr. Clark was used. Under these conditions, no permanent deterioration resulted, the oil on each application of voltage being fresh oil.

I have prepared three illustrations showing the results. Fig. 3 shows the effect of applying 30 kilovolts to oil under the conditions given. I have shown the individual points obtained in getting an average 100 per cent point. The variation is very wide; from 8 per cent to 250 per cent of the average.

The time was reduced to 70 per cent of the average time and new points were determined, getting a new distribution of break-

down time. That is, we applied the voltage for 70 per cent of this 71 seconds, or attempted to apply it for that long, and then cut off the voltage, stirred the oil, applying the voltage again, obtaining an average point which lies out at the value of 2. The time of application was then reduced to a little less than 40 per cent of the average time, obtaining another average point.

The testing voltage was reduced to 27 kv. (see Fig. 4). It was found that the average time for breakdown was 326 seconds.

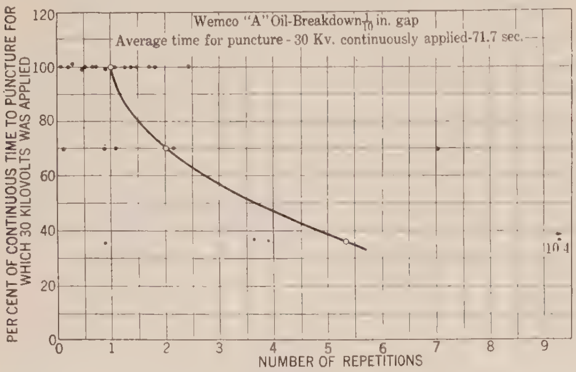


Fig. 3

Following a similar plan, we get a somewhat steeper curve than the one given for 30 kv. You understand, this is the same material, and that no permanent deterioration could occur, and yet we get a curve of this new shape. If we had had all these points lying right on the average point, instead of spread over a wide range as they are, then as soon as we had reduced the time to 70 per cent of the average time, we would have obtained no breakdowns. I realize that the number of points given here is not enough for complete proof, but it checks very well with the theory given.

I have taken the two curves shown before, and plotted them together in Fig. 5, showing the differences obtained, and also plotting a third curve which has the equation $R\ T\ =$ a constant. The object of this curve is to show that we can obtain almost any law by the conditions of test used; that is, even with the same

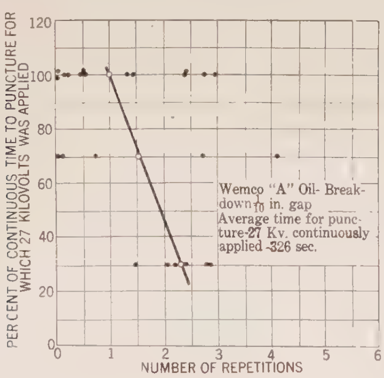


Fig. 4

dielectric, we can get $R\ T$ with a decreasing value, or with an increasing value.

Let me repeat then, in a few words, the ideas I have tried bring out in this discussion of the paper.

First, Mr. Clark's paper explains the shape of the curves in Fig. 8 to 18 by the presence of a permanent deterioration in the dielectric. I have presented evidence attempting to show that it is not necessary to assume permanent deterioriation to explain the shape of the curves, the evidence being, first, an actual experiment by Mr. Rayner in which no permanent deterioration occurred with similar dielectrics; second, an analysis of Mr. Clark's curves on another assumption; third, similar experimental curves where no permanent deterioriation did occur.

It seems probable to the speaker that in actual tests the curve shape is the result of a combination of two factors, variation and deterioration. Only more consistent results for identical tests can determine this point.

The most likely criticism of this discussion is that we are not dealing with the same thing in solid as in liquid dielectrics; that when we put a pair of electrodes down at a certain point on the solid dielectric, that point has certain properties which we will determine. Different points in the dielectric, it may be said, will vary widely, but a given point has rather definite properties, depending on the location of the electrodes.

Of course this is a rather good point, but we can see that because these variations are so very wide there must be something other than just a difference in the quality of the material to explain these wide variations. Perhaps a very slight variation in test voltage may cause it. Perhaps the distribution of charges in the dielectric may cause the variation. Perhaps where we have it immersed in oil, actual movement of the oil due to osmosis in the fibers of the insulation may cause it. Perhaps a slight shift or change in pressure or distribution of pressure of the electrode occurs. I do not offer a complete physical explanation based on

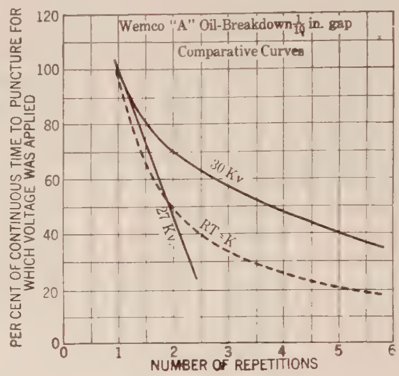


Fig. 5

this other assumption, but I do feel that we are in danger in interpreting results based on averages determined from a few points which vary as widely as those shown in Mr. Clark's tests.

Herman Halperin: It appears to me that the results of the tests in Mr. Clark's paper need not alarm the makers and users of high-tension, impregnated-paper insulated cables.

Figs. 2 and 3 of the paper show that a preliminary application of voltage, equal to about 60 per cent of the normal rapidly applied breakdown voltage, results in deterioration of only about 5 per cent and that after a rest period of three minutes the original dielectric strength is entirely recovered.

For the 12-kv., three-conductor cables purchased by the Commonwealth Edison Company in 1924, the normal rapidly applied breakdown voltage on the new cable at the factory would be about 100-kv. to 150-kv. The full-reel, high-voltage tests which were applied to this same cable was 32½ kv. for five minutes and this voltage corresponds to only about 25 per cent of the normal rapidly applied breakdown voltage of the cable. The acceptance test on the cable after installation and the subsequent proof tests are made at voltages considerably lower than those of the full-reel, high-voltage tests at the factory. The transient voltages, as found at several substations by means of needle gaps, are seldom as high as 32½ kv., when operating the cable. Therefore, the ratio of the extra high voltages that as applied to cables to their normal rapidly applied breakdown voltage is considerably below the ratio of 60 per cent which Mr. Clark used as his previous application of voltage, as pointed out in the previous paragraph.

In Fig. 4 the effect of applying for 2½ minutes a voltage of

about 65 per cent of the normal rapidly applied breakdown strength, is shown to cause a decrease of about 20 per cent in the instantaneous breakdown value of the insulation and the decrease in the voltage time curve at three minutes is only 12 per cent. So one wonders whether or not the effect of this previous application of a high voltage would be further decreased if the voltage-time curve were extended to a matter of hours, months, or years. As I have previously pointed out, in testing high-voltage cables, instead of using 60 per cent or 65 per cent of their normal rapidly applied breakdown voltage, the tests are at about 25 to 30 per cent, so the effect of those tests are further minimized to a very small amount, as may be deduced from Mr. Clark's work.

In Fig. 7, the difference between Curves 2 and 3 show the effect of the long-time application of voltage at a somewhat lower stress. The difference between the two curves is only 3 per cent or 4 per cent; hence it appears that nothing conclusive can be drawn

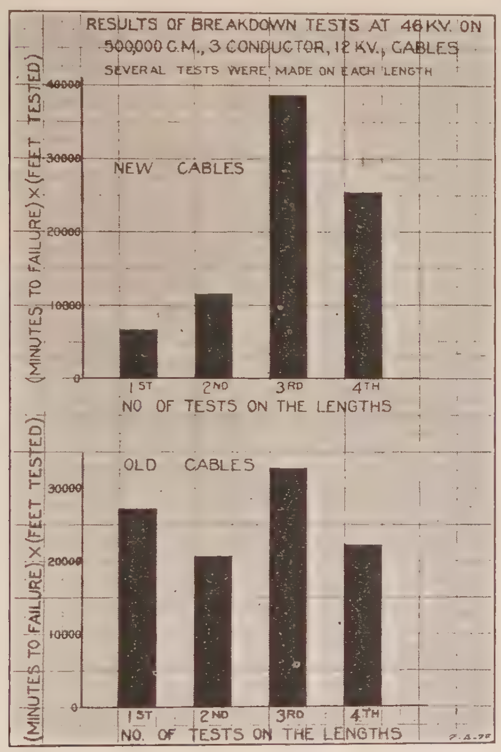


FIG. 6

as to the effect of this application of 3300 volts for seven days, for any one familiar with breakdown tests knows that test results, which show only a slight difference in dielectric strength, do not definitely prove any point, because the individual test results are liable to vary about 10 or 25 per cent. In connection with this curve, it is gratifying to learn that Mr. Clark expects to continue this work of the effect of long-time applications at lower voltages. The stresses which he is using for long-time application correspond to about the stresses used in full-reel high-voltage tests at the factory; after correcting for the thickness and form of the insulation.

Last year the Commonwealth Edison Company tested several 200-ft. lengths of three-conductor, 12-kv. cable. Some of these lengths were new cable as received from the factory and others were used cable which was removed from the system due to failures. The tests were made at 46 kv. three-phase with neutral grounded, and were continued until breakdown occurred. When a given length failed, the portion near one end was removed in case that portion was short; that is, if we had a 200-ft. length and the failure occurred at the 175-ft. mark, the 25 ft. were removed, a pothead was attached at that end and the test was repeated. If the failure occurred near the center of the length, a short section of cable including the failure was cut out and a joint made. Then the length was again ready for test. This was repeated on the various lengths, with from three to six tests on each length.

In the accompanying Fig. 6, the results of the tests on new cables are shown in the upper portion and those on old cables in the lower portion. In order to take into account the fact that the length of a given section of cable decreased due to cutting off portions, we plotted the product of the minutes to failure and the feet tested, against the number of the test on the length. For instance, on the second test, we took the results of all of the second tests on the various lengths, multiplied the minutes to failure of each section by the length of that section in feet, averaged all of these products, and obtained an ordinant of about 11,000. In general, the increase in the life of the new cable was very marked, while on the old cable the product of the minutes to failure times feet tested remained practically constant. If the item of feet tested had not been considered, then the increase of minutes to failure would have been greater for both old and new cables than shown in the chart.

Similar tests at higher voltages have been made on three-conductor, 33-kv. cable and the results are similar to those shown in the figure. That is, on the 33-kv. cable the average time that the section withstood the second and third tests was greater than the time which it withstood the first and second test, respectively.

These tests, which were made at nearly four times the operating voltage, indicate that one application of voltage of five to fifteen minutes at three or four times the operating voltage should produce practically no deterioration of the cable and should not affect its life in service.

E. S. Lee: In connection with Dr. Slepian's remarks regarding the effect of small laminations of the material as opposed to a greater thickness of the material, I want to bring to you something that we have noted, to see whether other folks have noted it because I think it is of great interest.

In Fig. 7 herewith results of dielectric strength tests on some black varnished cloth with both direct and alternating current are shown. It is interesting to see that while the relation between breakdown voltage and thickness for both alternating

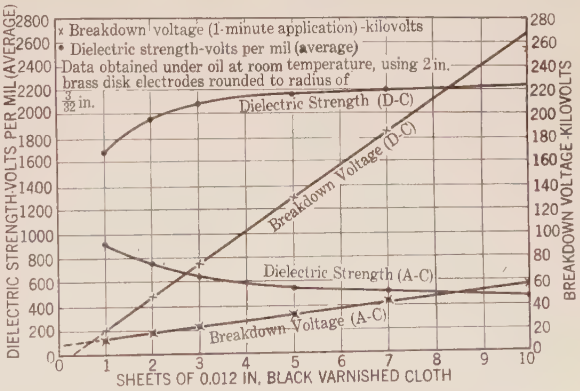


FIG. 7

current and direct current is approximately linear, the relation between dielectric strength and thickness for alternating current and direct current are quite different. This follows because the breakdown voltage-thickness curve with direct-current (extrapolated) cuts the x-axis, while the breakdown voltage-thickness curve with alternating current (extrapolated) cuts the y-axis.

The point I want to bring to you is this: While the a-c. curve says we have a given voltage with no thickness, and the d-c. curve says we have a certain thickness with no voltage, the point I want to make is that they probably both go through zero. Whatever is happening there, then, appears to

be happening within the thickness of one sheet of material. This bears out what Dr. Steinmetz has said: that we will have to study very small distances between electrodes in our study of insulation.

Just one other point: I did just as Mr. Halperin did in taking Mr. Clark's results and referring them to rated cable voltage and test voltage, and I came to the same conclusion that he did: that we were not in that range. But I noticed that when voltages occur on the system within 200 or 300 per cent of normal rated voltage, they come within the range of Mr. Clark's results. So it may be that in cable operation the results shown by Mr. Clark do enter.

R. W. Atkinson: As in the case of the discussion of Mr. Clark's paper authors of papers presented before the Institute are often criticized by physicists and engineers because not enough data are given, and authors are criticized by the Institute management because the papers are too long. These viewpoints are not always mutually exclusive, but very often they are, and an author always has quite a problem to meet both viewpoints, which are both very well taken. But usually a compromise must be arrived at, and usually both sides have some remaining good grounds for criticism.

I am very glad that Dr. Whitehead and Dr. Slepian have emphasized the fact that the pyroelectric theory of breakdown brought out by Dr. Wagner and Dr. Steinmetz is limited in application. Unquestiomably this theory can explain breakdown in many cases and unquestionably in many cases breakdown is of that character, but I am convinced that in many cases it is not.

There is one conclusion in Mr. Clark's paper that is very directly applicable to cable insulation in general. I do not know that it makes very much difference whether the explanation of the conclusion is deterioration, or whether the explanation is the random effect suggested by Mr. Crago, but this conclusion is that the total breakdown time for a given voltage is often or usually somewhere nearly independent of whether one test is made on a cable or several. If insulation will break down at a given voltage on an average in one hour, it does not make a great deal of difference whether it is ten 6-min. tests or one 1-hr. test.

That is given with qualifications in Mr. Clark's paper, and I think the qualifications apply. But in general it has seemed in tests on samples of cable insulation and in reel lengths that that general conclusion applies.

F. W. Peek, Jr.: It is a well established fact that when voltages above a certain value are applied to insulation, damage is done. If a succession of over-voltages is applied, the effect is accumulative. This is perhaps more simply shown by the following experiment with impulses of short duration than by Mr. Clark's data. A voltage is readily found at which a single impulse will cause failure. If this voltage is lowered somewhat it may require ten impulses, to cause failure; at a still lower voltage one hundred, etc. Finally a voltage is reached where there is no failure on any number of applications. The cumulative effect of the successive impulses of over-voltage is not a pyro effect; it is not due to an accumulation of the heat from each application because it does not depend upon the time between applications. It is caused by a disruption or tearing apart of the material without burning. Of course, this disruptive effect is quite different with different types of insulations. With certain electrically brittle insulations the effect is marked. With insulation built up of laminations filled with oil the effect is probably a minimum because damage is repaired by the flow of the oil. I think that Mr. Fisher's discussion illustrates this.

In addition to the above disruptive effect, there is without doubt a pyro effect. The pyro and conduction effect becomes predominant in certain insulations for moderate "over-voltages" and comparatively long times of application. The theory, now generally known as the Wagner theory, fails, I believe, in that it does not consider all of the variables. The mistake must not be made in neglecting either the disruptive or the pyro and conducting effects. Whether one or the other is the predominant cause of failure depends upon the conditions.

D. W. Roper: In the test described by Mr. Halperin the lead sheath of the cable was very thoroughly grounded so the operators could go along and feel the sheath with their hands and determine the location of the hot spots which developed through local heating. These hot spots were marked, for the purpose of orienting the subsequent failures. The failure occurred in the maximum hot spot in about 40 per cent of the cases. In 25 per cent additional, the failure occurred not in the maximum hot spot, but in some other spot where the heating was appreciable. About 35 per cent of the failures occurred where the temperature was normal, that is, where there was no hot spot. So that the number of cases in which there was no pyroelectric effect was about equal to the number of cases in which the heating was apparently due to the pyroelectric effect described by K. W. Wagner.

C. E. Skinner: I have been very much interested in Mr. Clark's conclusions, particularly in view of my paper entitled, "Energy Loss of Commercial Insulating Materials when Subjected to High Potential Stress," published in the 1902 Transactions of the Institute, page 1047. I would especially refer to the numbered paragraphs, 1 to 8, inclusive, pages 1050 and 1051. My tests were made with the view of determining the effect of continued stress of various intensities and frequencies, but many of the conclusions from these tests anticipate those given in Mr. Clark's paper. For example, this statement appears, "The final breakdown in fibrous materials usually results from the burning of the material and not from mechanical rupture." My paper discusses the general question under the headings, "Variation of Temperature due to Variation of Stress," "Variation of Loss due to Variation of Temperature," "Variation of Loss due to Variation of Voltage," and "Variation of Loss due to Variation of Frequency." Mr. Clark has given the results of experiments made from a somewhat different viewpoint and it is naturally gratifying to find that where parallel conclusions are reached, they are substantially the same as those arrived at by the very crude instruments and methods available to us twenty-two years ago.

V. M. Montsinger (by letter): Mr. Lee has mentioned one very interesting point and that is the variation of dielectric strength with thickness. I cannot quite agree with Mr. Lee in that if the first layer is neglected, the points fall on a straight line on coordinate paper, or in other words that the dielectric strength is proportional to the thickness.

An examination of a large number of tests made on various kinds of fibrous insulation shows that in almost every case the points fall on a straight line on log-log paper. This means that the strength vs. thickness can be expressed by the expression:

$K.\ V. = A\ T^n$, where A is a constant T the thickness and n a numerical value depending mostly on the treatment of the material.

If the material is untreated the value of n is close to unity. If the material is well oil-soaked or varnished, the value is around $^2/_3$ or perhaps $\frac{3}{4}$. However, if the layers are very thin in the order of a few mils it is often found that the strength of the first layer is higher than the line indicates it should be. The effect is perhaps the same as what we find for air and oil, namely for very small distances the volts per mil goes way up and departs entirely from the law that holds for the larger thicknesses.

As stated in Mr. Clark's paper, there is scheduled for publication in the near future, an article by Mr. Clark and myself on the subject of dielectric strength vs. thickness and in which the subject is discussed more thoroughly than is possible here.

In reference to Mr. Bratt's formula, which states that the maximum strength is inversely proportional to the frequency of the applied voltage, I would like to point out that while strength

decreases with an increase in frequency, it is not in any way inversely proportional as indicated by the formula.

The results of a large number of tests covering a range of frequency from 25 to 420 cycles show that the factor F should have an exponent M whose value is approximately 0.137 for solid insulations. The difference in strength depending on whether the value of the exponent is 1 or 0.137, is of such a large magnitude that it cannot be neglected. For example, if the strength was inversely proportional to the frequency, the dielectric strength at 420 cycles would be $^1/_7$ or approximately 14 per cent of the strength at 60 cycles. As a matter of fact for solid insulation the 420-cycle strength is approximately 75 per cent of the 60-cycle strength.

Full details covering this subject are given in my paper on "Effects of Time and Frequency on Insulation Tests of Transformers" appearing in the March 1924 issue of the A. I. E. E. JOURNAL.

F. M. Clark: I would like to put one thing over and that is that I do not believe that I am attacking the pyroelectric theory of insulation failure. For that reason, I have been glad to hear Dr. Whitehead and others rise to the defense of the pyro theory in statements with which I can heartily agree.

Any discussion of the heat theory of insulation failure, generally involves, sooner or later, a discussion of "weak threads," conducting particles and the like, and such a talk usually ends in a thorough condemnation of the paper manufacturer. I can not agree that the paper or cloth, or whatever may be the solid concerned, is the sole seat of the weak spots involved. There are all sorts of ways in which a weak spot may be formed not even remotely involving the characteristics of the solid itself. From work which I have done, enumerated in this paper and otherwise, it seems as if a weak spot might actually be formed as a result of the voltage application. For example, we know that some molecules are unsymmetrical and polar. They thus possess the property of attracting other molecules. The water molecule has such a property and if present in oil it would become attached with its positive pole or its negative pole as the case may be toward the second molecule involved. This in effect would lead to a molecular polarization in the liquid dielectric possessing all of the characteristics necessary for a weak-spot formation. A thorough study of Fig. 17 will reveal the possibilities of this idea, in connection with the apparently cumulative effect of voltage upon insulating materials.

If we assume this explanation, it will explain a large number of the questions raised in the discussion, I cannot take up all of these but there are several to which I desire to reply.

Mr. Fisher and others have pointed out that apparently with viscuous materials such as impregnating agents the effect of voltage application on cables is negligible. In view of the fact that the cable cited by Mr. Fisher was apparently very well treated and voids eliminated no objection can be raised on that score. But does Mr. Fisher not consider the fact that it is somewhat remarkable that every time his cable broke down and he repaired it, the next break was at about the same voltage? If we assume that each time a break appeard, we are removing a weak spot, the next breakdown ought to be higher. In other words, by removing the weak spots of the cable, the actual breakdown ought to rise gradually with each succeeding test. The fact that it does not, might be explained from the standpoint of a cumulative voltage effect.

I can only remind Mr. Skinker that it is realized that further study must be given to the effect of voltage application involving longer times that an arbitrary limit of 15 min. As stated already, however, this phase of the research is at present being investigated and will be reported upon at the appropriate time. Furthermore, as far as can be detected with the oscillograph, the effects of surges cannot be used to explain the voltage effects set forth. The possibility of surges has been considered and eliminated. Mr. Luke has referred to the researches of Rayner on oiled cloth in which a long-time voltage application produced an effect which did not disappear during a rest period. Although no oiled cloth has been investigated in these researches, there is no apparent reason why its behavior should not correspond with that cited for oiled paper. Certainly its behavior must not be confused with that given for varnished cloth which Mr. Luke has apparently done. If we accept the case of oiled cloth as paralleling that for oiled paper then there should be no recovery from the voltage effect. This is clearly illustrated in Fig. 4 of the paper.

Mr. Luke furthermore points out the mechanical effect of impulses. These results are in agreement with work of similar nature with which I am familiar. Apparently Mr. Luke has misunderstood the statement on the second page with reference to the behavior of fibrous oil-treated material heated between voltage applications and to mica. (Figs. 17 and 18). All actual voltage application has been carried out at room temperature. When the insulation has been heated between voltage stress, it has been cooled to room temperature before the next application of voltage. We have never been able to obtain evidence of an additive voltage effect under such conditions. The effect is cumulative and somewhat erratic as shown in the figures mentioned but in no sense strictly additive. Mica has always been found rather erractic in tests of this sort but the results are in general of the same character.

Mr. Bratt has brought out the necessity of carefully distinguishing between an instantaneous breakdown and a thermal breakdown. This necessity has been recognized throughout and it is for that reason that the paper has been carefully separated into three parts. The very short-time test results are shown in Figs. 1, 2 and 3. Figs. 8 et seq. deal with breakdown involving thermal considerations. These two groups are connected by Figs. 4, 5, 6 and 7 showing the time-voltage relation involving a breakdown from those of "instantaneous" character to those involving thermal considerations.

Mr. Crago has cited the work of Rayner in which a stress application of 11,000 volts produced a break in 12 sec. which was unaffected by a previous voltage application followed by sufficient rest period, the time of rest demanded being about 2 min. A break involving only 12 sec. is of the same category as those designated in this paper as rapidly applied tests, involving roughly 10 sec. For breaks of this character, it is shown that a decided recovery of the insulation occurs during a rest period after a voltage application. Furthermore, as given in Figs. 2 and 3 the rest period demanded is approximately 2 min. although influenced somewhat by the value of the initial voltage stress.

Mr. Crago has claimed that the insulation after being stressed, returns not to the original value nor to a poorer condition but to a random point, which if I understand him correctly may be even better than the original. I can merely say that we have never observed that the strength of insulation when once subjected to high-voltage stress has returned to a value better or even as good as the original when such strength is estimated by tests involving thermal considerations, except in cases where the material has specifically been given a poor drying and oil-treating process. Here, the results have obviously involved factors such as a further drying-out process, and the like, whose effect has overshadowed the effect of the applied voltage.

Mr. Crago has objected to the conclusions of this paper on the ground that the results are based on tests involving wide variations which he calculated as amounting in some cases to as much as 50 per cent from the mean. He cites researches to support his contention using oil as the insulation investigated and draws conclusions based on the data illustrated in his Figs. 4 and 5. And yet the results upon which his conclusions are based show such wide variations that it is surprising that they should be submitted as scientific data. Thus he stated that the average relation of maximum to minimum of the 100 per cent points in the data which I have submitted is as 6.3 to 1. The relation existing for the corresponding values of his research are as 33 to

1 for Fig. 4 and as 118 to 1 for Fig. 5, an average ratio of maximum to minimum of 75.5 to 1. Stated otherwise, from Mr. Crago's calculations of the variations in the data which I have submitted the deviations for the fibrous materials investigated ranges from as low as 20 per cent of the mean to values as high 185 per cent of the mean. In Mr. Crago's work he states that the variations of his Fig. 4 range from 8 per cent to 250 per cent of the mean value. For his Fig. 5, a study will show that the values range from about 2 per cent up to approximately 297 per cent of the mean value. Obviously, the factors involved in Mr. Crago's work have not been sufficiently controlled and his results are condemned by his own contentions.

But suppose we consider Mr. Crago's results further. Why should his data suffer such a wide variation? Mr. Crago bases his experiments upon a time-voltage relation in oil. A study of pure liquid dielectrics and clean, dry oil in particular will reveal the fact that although the time lag is more pronounced than in air and other gaseous dielectrics, yet in no way is it comparable to that which has been found by Mr. Crago. It is only in the case of wet oil or oil containing contaminating dust or fibers that such a marked time-voltage relation can exist. Thus obviously what Mr. Crago is measuring is not the dielectric strength of the oil and therefore not the effect of voltage upon oil but rather the time factor needed to line up these contaminating materials in the 0.1-in. test gap. Thus the time factor involved will entirely depend upon the chance arrangement of these materials at the time of the voltage application together with the resistance which they offer to being sucked into the dielectric field. This explanation gives a reason why Mr. Crago should get two entirely differently shaped curves when he uses 30 kv. as compared to 27 kv. in his experiments. The 30 kv. will rupture, he finds, in 71.7 seconds as opposed to 326 seconds when 27 kv. is used. The lower voltage should obviously take longer to line up the fibres, dust particles, etc., in the test gap. This, however, is not the whole story. In his Fig. 4 the minimum time to puncture is 8 per cent of the 100 per cent time value or 5 sec. In Fig. 5 the minimum time to puncture is 2 per cent of the 100 per cent time value or about 6.5 seconds. Unless the experiment was very carefully controlled, this means that the oil broke down almost immediately when the full voltage was impressed across the gap. Such a breakdown could be explained by the chance "bridge" arrangement of a contamination in the gap at the moment of voltage application. One would not expect under these conditions that the number of repetitions of stress times the time of each repetition to break down would be constant. Rather would one expect that with high voltage and therefore a very short time of repeated voltage application, the product of the factors mentioned might possibly be greater than the original continuously applied (100 per cent) value, since in this case the breakdown would almost entirely depend upon the chance arrangement of a conducting bridge across the test gap at the time the voltage was impressed. With lower voltages and longer time for the repeated voltage application, obviously the second factor, the sucking of the contaminating material into the field would play a much larger part. The product of $R \times T$ might even be smaller than the original 100 per cent time value. This is because of the fact that although the importance of the "sucking actions" of the field has not been diminished to any great extent, nevertheless the possibility of the chance formation of a bridge has been materially increased by breaking the voltage application up into steps and the stirring up of the oil between each stress application. I can thoroughly agree with Mr. Crago that under the conditions of his experiments, he could obtain almost any law by the conditions of the test used.

The case of a 33-kv. cable has been cited by Mr. Halperin in which the average time a section withstood the second and third test was greater than the time it withstood the first. It must be remembered that in cable work failure may be due to a cause entirely foreign to the phenomenon investigated in this paper. For example, cable engineers recognize that a fundamental problem, in the manufacture of their product is the preparation and impregnation of the insulation in order to secure thorough drying and the absence of voids. When a cable fails prematurely it is generally assumed poor, not because of the cumulative effect of voltage, but because of poor treatment, drying and other mechanical factors in its manufacture. Thus in the case of Mr. Halperin's 33-kv. cable, is it not possible that the first failure, the second failure, etc., can be traced directly to some such cause. the removal of each successive section ought therefore to lead to higher and higher breakdown stress until only that insulation is left which contains a minimum of mechanically weak spots and thus allows the manifestation of the deteriorating effects due to the applied voltage. In the experiments of this paper, the use of a small vacuum-dried and well impregnated test specimen together with parallel-plane electrodes has prevented all such treating phenomena from being of major value and has thus allowed the effect of each voltage application an important place in the ultimate breakdown.

CORONA IN OIL[1]

(Crago and Hodnette)

New York, N. Y., February 11, 1925

J. B. Whitehead: It has been known for a long time that liquid dielectrics of even the best type are subject to a moderate electrolytic dissociation, which means that the ultimate parts of the dielectric are at all times, some of them, in a state of separation as regards their component charges—not many, but some of them.

The laws of conduction in liquid dielectrics (and all liquids have some conduction) are in every way consistent with the theory of dissociation that has been built up for gases. It is possible to ionize liquid dielectrics. It is possible to subject them to a regular ionizing agency, and it is possible to measure the rate of re-combination of the ions so formed. We have plenty of evidence to prove that liquid dielectrics may be ionized.

So I think it was a great pity that Messrs. Crago and Hodnette should have gone to such great trouble to show that under certain circumstances oil may have an appreciable conductivity. The fact has long been known.

Also, I would like to ask them whether they considered the use of the corona-tube as a method for investigating conductivity. It appears to me that if they had used a small tube and a small wire, the tube being filled with many holes, and immediately outside of it an insulated electrode, that they would have had not nearly the trouble in finding a method for measuring the current caused by the conductivity of oil.

M. F. Skinker: While Mr. Crago and Mr. Hodnette were interested primarily in securing an answer to an engineering problem, it is to be regretted that they did not add a few refinements which would have insured freedom from errror.

Let us see what is required for an accurate scientific investigation and try to outline what should have been done in these experiments.

It is necessary that all conceivable variable factors be kept constant except those which you are attempting to correlate by the investigation. It sometimes happens that a factor cannot be kept constant and a correction must be made in the final result. This, however, should only be done as a last resort.

In the experiments on corona in oil, we have to consider the electrical measuring devices, the oil, the electrodes, and the oil in contact with the electrodes. Fortunately, nearly every one takes care to see that the electrical measurements have a high degree of accuracy.

With regard to the oil, the authors only imply that it was clean and dry by saying the dielectric strength indicated good oil. Why did they not attempt to purify the oil first? I might suggest that if some fine pieces of metallic sodium, or a little aluminum chloride were mixed in the oil and then filtered, this would have removed *all* the water and almost all other impurities.

1. A. I. E. E. Journal, Vol. XLIV, March, p. 219.

By an appropriate cover for the testing vessel impurities could have been kept out during the experiment.

Care must be used with parallel plate electrodes which are close together for the electric stress may well be high enough to alter the spacing by several per cent.

It should also be well known that catalytic action of the brass or common metals in the oil can materially affect the results of any experiment. The simplest and most effective way of preventing this would have been to gold-plate all metallic surfaces in contact with the oil, as done by Lee and Kurrelmeyer in their experiments on gases.

With these simple precautions the authors could have collected data that was really worthy of definite conclusions.

The test of accurate data is in the following question: "Can this experiment be reproduced in another laboratory and exactly the same results obtained?"

The test of properly recorded work is in the question: "Have all the conditions under which this experiment was performed been recorded, so that others may draw their own conclusions from the data?"

If these two questions cannot be answered in the affirmative, the experiment is hardly worth publishing.

I make this plea for more scientific work because I believe it is only in this way that we may eventually solve the insulation problems.

J. A. Duncan: There are two significant statements in the paper by Messrs. Crago and Hodnette, namely: "This oil had been used for miscellaneous testing purposes previous to these tests, but still had a dielectric strength of about 33-kv. r. m. s., which is an indication of good oil," and, "Unfortunately, the water content was not determined for the tests referred to, and the oil was later destroyed."

F. W. Peek showed in 1915 that a sample of dry transil oil had a dielectric strength of 62.3 kv., and that the addition of moisture to the extent of one part in twenty thousand caused a 50 per cent decrease in dielectric strength, while twenty times this amount of moisture only reduced the dielectric strength sixty per cent. This certainly shows that it is the first trace of moisture which causes the greatest decrease in strength and indicates the importance of the removal of this trace from oil which is to be used for any scientific purpose. Of course, I do not know how "Wemco" oil compares with ordinary transil oil, but whatever the relation may be, it is safe to say that comparison would probably be more favorable to a recently and carefully dried sample of Wemco than to one with a long and unknown past.

I should like to suggest with Drager in the very paper cited by the authors that it may be the presence of moisture which provides the conducting particles mentioned by the authors in the first paragraph on the fourth page of the paper. On the other hand, attention was called to the fact that "as the voltage stress becomes very great, molecules may be torn apart into plus and minus ions." Evidently they mean to consider the possibility of ions being formed by the actual disruption of the hydrocarbon chains into parts, each containing one or more carbon atoms, this in addition to those formed by the simple removal of an electron from the molecule. Long carbon chains such as we have to deal with here are so easily broken up by the action of heat that it does seem reasonable to suppose that they might also be broken up by the action of the electric field. If such ionization does take place, and Dr. Whitehead has just told us that some ionization is known to occur, it could be identified by its effects on certain properties of the oil such as the temperatures at which various components of the oil would distill off from the remainder. When these long molecular chains do break it is not generally at the center. We have the possibility of ions containing anywhere from one carbon atom to one less than the normal number in the original oil molecule. The products of recombination will then vary anywhere from neutral molecules of two carbon atoms, which would be ethane gas, to one of two less than twice the normal number of carbon atoms. There, abnormally long molecules might again ionize and some of the ions recombine to form still longer and therefore heavier molecules. Such breaking up of the molecules and recombination into molecules both lighter and heavier than normal is known to take place in oils when heated to sufficiently high temperatures. In fact, this action is the very basis of one of our well-known commercial processes for the manufacture of gasoline from crude oils.

I am sorry that the experiment on corona in oils was not continued far enough and long enough to give these recombinations a chance to occur in detectable amounts. The products are easily detected when present. The abnormally heavy ones will settle to the bottom of the oil as a sludge. The abnormally light components will distill off even at near room temperatures and are detectable by various means. There is one method of detecting the formation of the gases which although known long before my time was discovered independently by me in a very striking manner. It was by the simple process of bringing a lighted gas jet a little too near the mouth of a flask half filled with transil oil which had just been heated to slightly above the cracking point. In this case I am forced to join in the conclusion that unfortunately that sample of oil is no longer available for further tests.

One of the conclusions is "That the effects noted are produced in a very few minutes and are temporary in nature," and a curve, Fig. 7, is drawn which shows that the dielectric strength passes through a cycle. In this connection it seems well to emphasize the fact, and this applies not only to the experiment under discussion but to all others as well, that because one property of a substance passes through a cycle all other properties pass through a cycle and return to their origianl value. One could name an endless number of cases in which this is not so, and Dr. Hans Staeger mentions one which is particularly applicable here.[1] Under the influence of metals as catalyst, the acidity of an oil, for example, may pass through repeated cycles, while the sludge formation and contamination of the oil proceeds cumulatively with the total time.

In that connection, I only want to refer to the conclusions which we have considered most important, and see whether they have not been drawn from the data presented. Probably the most important is a negative conclusion: "That since the effects described in this paper all occur only at voltage stresses which produce visible corona, they do not exist in properly designed commercial apparatus."

This was the main object of the tests and was, I believe, proved rather definitely.

The other conclusions you have already heard and they are in the paper. We feel that they are not extremely definite conclusions, but have been definitely based on the work, the results of which have been given.

I might say in connection with this catalytic action of brass electrodes that Mr. J. E. Shrader of the Westinghouse Company several years ago made a large number of tests on conductivity of oil using gold, copper, silver and brass electrodes, with results so nearly identical that differences were within the limits of experimental error.

I wish to say in conclusion that I do feel that the paper presents data which should be useful as a guide for future work, that we get these effects at rather large distances from the electrodes, and that they do not occur below corona voltages.

A. C. Crago: I realize that those discussing our paper, "Corona in Oil," have been at a disadvantage because the paper was printed within the last week. I believe that the scope of the tests has been somewhat misunderstood. For that reason I wish to give in more detail the reasons the tests were made and the

1. *Schweitz Elektrotechniser Verein Bulletin*, March 1924.

conditions under which they were conducted, reading two paragraphs from the paper.

The tests as they were originally planned were intended to discover whether there were deteriorating effects in oil below a voltage which would give visible corona with certain type of electrodes in the oil. We, therefore, first made an attempt to find these effects. This was naturally an engineering problem, which we expected to solve in a short time. Since we did not find any effects below corona voltage, we continued the work further with higher voltages. The conditions were not greatly changed in extending the work.

Quoting the paper: "In the latter part of 1923, Professor H. B. Smith of Worcester Polytechnic Institute raised the question of the possibility of the temporary lowering of dielectric strength of oil due to high local voltage stresses, such as might occur at sharp corners in a transformer, although visible corona might not be present. Investigations were undertaken to determine this effect at potentials both below and above corona voltage." And:

"It is not the desire of the writers to give an impression of great accuracy in the quantitative results obtained. As in most cases with dielectrics, the variations were wide. To a certain extent, tests used in producing the curves are selected tests. However, the tendencies and shapes of the curves are definite and are found in practically all of the tests made. It is this rather than the quantitative results which should be emphasized."

Let us take the discussions in the order in which they were presented. Professor Whitehead has expressed regret that we have gone to the trouble to show that there is electrical conductivity in oil, and points out that this conductivity is influenced by radioactive or other radiating sources. If the sole purpose of the paper had been to demonstrate the existence of these two well known phenomena, we agree that the paper would be without value. I believe that Professor Whitehead has misunderstood the purpose of the paper, which was not to show that there is a conductivity, but more to show the effects of a particular source of ionization, which may be found in practise. The use of the "corona tube" was not considered.

Mr. Skinker asks us two questions, which I will quote: "Can this experiment be reproduced in another laboratory and *exactly* the same results produced?" Certainly and emphatically no. The word "exactly" cannot be used properly with respect to experimental results.

"Have *all* the conditions under which this experiment was performed been recorded, so that others may draw their own conclusions from the data?" *All* conditions have, of course, not been recorded. This is a physical impossibility. Whether conditions *necessary for the conclusions drawn* have been given must be judged by those who read the paper; not by the authors.

I might say in connection with the catalytic action of brass electrodes, mentioned by Mr. Skinker, that Mr. J. E. Shrader of the Westinghouse Research Laboratory points out in an unpublished paper that the conductivity of oil using gold, silver, brass, copper and nickel electrodes show no greater differences than the experimental errors.

Mr. Duncan states that "dry transil oil had a dielectric strength of 62.3 kv." omitting to state; 1. whether the value is r. m. s. or peak; 2. the shape and spacing of electrodes. This figure thus cannot be compared with that of 33 kv. r. m. s. given for Wemco "*A*" tested in the present Westinghouse standard-test cup. Most of Mr. Duncan's discussion, although raising interesting possibilities and explanations of certain phenomena, is outside the scope of the paper and does not affect the conclusions drawn.

NOTE See also discussion of this subject by Joseph Slepian page 630.

USE OF AN OSCILLOGRAPH IN MECHANICAL MEASUREMENTS[1]

(CURTIS)

NEW YORK, N. Y., FEBRUARY 12, 1925

J. R. Craighead: Mr. Curtis has given a great deal of attention to pushing the use of the oscillograph into fields decidedly beyond that for which the device was originally designed. The fundamentals of the oscillograph (that is, the natural frequency of the vibrator, and the photographic ability of light which can be placed upon the film) are such that values of the order that Mr. Curtis speaks of can be attained, but the general mechanical construction, and details, have been laid out with a view to practical operation in the shop and in power stations, rather than reaching the extreme values which Mr. Curtis has attained.

I made a few comparisons from the figures given in Mr. Curtis' paper. The width of the beam actually photographed on the film is usually of the order of $^1/_{16}$ in. It can be brought down considerably below that, but in the same oscillogram, the actual width of the beam photographed is dependent on the rate at which the beam is displaced; in other words, the same spot of light displaced somewhat slowly will produce a much wider beam than it will when displaced with extreme rapidity, because of the varying photographic effect as you proceed from the center of the beam outward.

Mr. Curtis is measuring, according to the text of the paper, by means of a comparator, distances of approximately 0.001 in. and these distances are being measured on a beam such as I have described which ordinarily would be $^1/_{16}$ in. wide, but which as his oscillogram shows he has been able to get down to much less width. Will he give us a word or two regarding the type of comparator he uses which enables him to place these beams in such a way that distances as small as 0.001 in., or less, as implied in some of his statements, can be correctly measured.

There is no difficulty, of course, in reading that distance on the comparator. What I am trying to get at is the question as to how he can apply the comparator to a somewhat indefinite line and get the accuracy spoken of. It is, of course, essential to place on the film the timing lines to which he refers.

In regard to the actual correctness of the observation, after the photograph has been made, one further consideration of importance comes in. The ordinary kodak film expands when you put it in the developer and contracts when you dry it, after taking it out. The amount of expansion and of contraction and the exact size of the film at the time the photograph is taken are all quantities which depend upon the exact atmospheric conditions and the exact method of treatment. Because of conditions of this kind, timing by lines very closely in the vicinity in which measurement is to be made becomes essential. These lines which Mr. Curtis has placed on his films, it seems to me, should be extended all the way across the film, if he is going to get correct measurements for some of the values which he has indicated as going to the extreme opposite side of the film.

F. V. Magalhaes: Mr. Curtis makes the statement: "Experiments have been made with different sources of light, but for the highest film speeds it is necessary to use an arc lamp."

No question is raised with regard to that particular statement, but it would be of interest to know what measure of success he may have obtained with other sources of light, presumably incandescent lamps, for use with the oscillograph.

In the laboratory, where the particular function which is being measured can be repeated until a proper record is obtained, it is quite possible to use the arc which provides an intensity and a quality of light which is very satisfactory for high-speed films. In the field it is sometimes necessary to use an oscillograph under conditions where it is difficult, if not impossible to repeat the function. The arc under these conditions introduces variables such that consistently good oscillograms are hard to obtain. It is an accomplishment, to my mind, to operate an oscillograph

1. A. I. E. E. JOURNAL, Vol. XLIV, January, p. 45.

continuously and without failure in the field. It means a careful watch on about a half dozen different factors or parts of the oscillograph, including the arc. When you get the results with the arc, they are very satisfactory, but it is difficult to handle, and it would be valuable indeed to have a satisfactory source of light such as an incandescent lamp, free from the mechanical and electrical variabilities that exist in the arc.

C. E. Skinner: Mr. Magalhaes has suggested the desirability of a light source easier to operate than the arc lamp. Mr. J. W. Legg's work has been done with an incandescent lamp, usually flashed at the instant of the taking of the picture, and I think his discussion will show that he has accomplished considerable in the way of speed in connection with the use of this device.

J. W. Legg: Practically all of the mechanical measurements made by Mr. Curtis have been made by electrical engineers in connection with electrical testing but have not been heretofore so fully described, and in some cases have not been so carefully worked out.

The writer's article in the February, 1923 JOURNAL (Vol. XLII, page, 111) on "Expansion of Oscillography," states: "Many purely mechanical movements can be detected and studied only through the medium of electricity and the oscillograph. Undesirable vibrations in machinery, noises, minute movements, momentary pressures, disturbances in the atmosphere, properties of materials and many other non-electrical functions have been studied with the oscillograph. Force or movement has to be transformed into a change in electric current through the medium of the carbon microphone, a special generator, a varying capacity or reactance, or the action of the piezo-electric crystal. The resulting current may be recorded directly by the oscillograph, or first amplified to suitable strength by the three-electrode vacuum tube." These various mechanical measurements have been made by electrical-apparatus manufacturers in conjunction with electrical tests on quick-acting circuit breakers, electric locomotives, synchronous-converter sets, and the like, but heretofore, have not been taken up by non-electrical apparatus manufacturers, except where the manufacturer is in close touch with the electrical industry, as is the case with some steam-turbine manufacturers.

The value of the various attachments which were made by Mr. Curtis for his particular oscillograph was realized by the writer when designing the oscillograph described in the July 1920 JOURNAL (Vol. XXXIX page 674). An improved optical efficiency and an incandescent lamp were substituted for the old arc lamp; all control apparatus was included in the main unit; a mechanical shutter and control mechanism were designed to cause transients to appear on desired parts of the film, and a fourth optical system was provided for the timing lines. A simultaneous-viewing scheme was proposed but not adopted at that time. The oscillograph described in the February 1923 JOURNAL has been furnished, for particular non-electrical work, with a simultaneous-viewing attachment which has one great advantage over that described by Mr. Curtis, in that viewing continues during the photographic exposure as well as just previous to it. The incandescent lamp is operated on abnormal voltage only during the photographic exposure, hence if the particular transient required does not appear during the extra-bright wave period, then the operator can be sure that it was not successfully photographed and may repeat the test without waiting to develop the film to find the failure.

The increased optical efficiency of the new portable oscillographs, including the six-element instrument, would have been a help to Mr. Curtis with his high-speed films. By arranging the film on the drum to come closer to the oscillograph optical slot, it was possible to use a much wider angle of convergence from the cylindrical condensing lens than was utilized in older forms, thus increasing the intensity of the record on the film in the same way that a larger diaphragm opening in any camera increases the exposure without enlarging the image.

The large-diameter drum, used by Mr. Curtis, is a necessity for extremely high-speed work. Such a large drum has not been required heretofore for electrical phenomena, a compact day-light-loading one being used for the same length films. Such a film holder has been planned with a differential shutter which gives a small fraction of a revolution exposure and then a complete revolution without exposure, followed by another fraction of a revolution exposure, and so on, until the exposures cover the whole film. Thus, several high-speed records may be taken of some transient phenomena which are repeated several times with intervals between each transient longer than the duration of each transient. In the electrical industry such a film holder would be ideal for showing repeated short-circuit phenomena on oil circuit breakers, and switches. For mechanical measurements, such a film holder with differential shutter, might be used to give several high-speed records of the effect on a material of a terrific blow repeated at definite intervals until the material is shattered. The transient and the oscillograph lamp may be controlled by the shutter shaft, while the film rotates at a slightly different speed to get the intermittent exposures in the proper sequence. If the film speed is to be great and the time interval between exposures appreciably long, several revolutions of the film may occur before the lamp is lighted again in time to take another exposure when the shutter opens the next time, etc.

Schemes for recording several mechanical and electrical values with a single vibrator element have often saved much time and expense in testing. Before the development of the new portable oscillographs, the writer frequently recorded five distinct mechanical occurrences and times with one vibrator, leaving the two other vibrators for electrical measurements. The inductive kick from the actuating coil of an electrically driven tuning fork gave sharp kicks to the wave at the rate of 200 per second (or whatever rate was desired) while a potentiometer was used to record the displacement-time curve of the plunger of a quick-acting trip magnet. Contacts with resistances were arranged for showing when the main circuit breaker contacts parted, when the arcing tips parted, when the contact separation reached ½ in., and when the contacts were fully separated. The other vibrators showed the current and the voltage characteristics of the trip circuit.

The use of the double carbon pile for recording pressures, stresses, accelerations, etc., was found to be quite limited in its application, since it is affected by sideways shock. To avoid this error, electromagnetic schemes were resorted to, which were so planned that the converters were not affected by any disturbance except the particular values which were to be recorded.

The step-by-step methods for measuring displacements, including an accurately made commutator with one tooth to every ten degrees (except for the last which was omitted) were found to be altogether too crude for most vibration studies. Special apparatus, operating on the electromagnetic principle, was designed which made it possible to record torsional vibrations of less than one one-hundredth of a degree (0.01 deg.) and less than ten-millionth of an inch (0.000010 in.), at frequencies as high as 2200 cycles per second. Furthermore, the calibration of these devices was constant, and was unaffected by centrifugal force or high-speed rotation.

The writer feels certain that there is a greater field for the oscillograph for observing and recording mechanical and other initially non-electrical properties, than there ever has been in the electrical industry. The advent of the six-element ocillograph and the extremely portable single-element oscillograph described in the December, 1924 "*Electric Journal*" together with Mr. Curtis' article, should open the way for mechanical engineers to study their own problems as never before.

C. H. Sharp: The question of the source of light has been raised by Mr. Magalhaes, and that is an extremely pertinent question. I should like to ask whether an attempt has been made (and if so, whether it has been successful) to apply the little tungsten arc in vacuum, a lamp that is known in England

as the Pointolite lamp, to this kind of work. That gives a very small source of light and I think one of very high intrinsic brightness.

Another thing that I wish to point out is this: that the oscillograph as it is at present constructed is essentially an ammeter. It utilizes the magnetic field produced by one turn, and that is all. Its sensitivity is limited by the fact that whatever field operates it is a field produced by a single turn in another field.

It would be an extremely useful thing if we could have an oscillograph which would set up a field from many turns, instead of only one. It would then become a high-resistance instrument, sensitive to extremely small currents, and, of course, requiring higher voltage to operate it. In other words, it would be a voltmeter rather than an ammeter.

We should not lose sight of the fact that the original oscillograph as proposed by Blondel a good many years ago was capable of doing this sort of thing. I refer to the oscillograph in which the moving element was like a Thomson galvanometer, in that it consisted of many little, soft iron needles on a quartz rod, suspended by a quartz fiber, in a magnetic field, and then actuated by another magnetic field at right angles, set up by coils which were in circuit with the current which was to be measured.

These coils evidently could either be of the small number of turns low-resistance type, making the instrument an ammeter, or of a large number of turns of the high-resistance type, making it a voltmeter. Thus, its theoretical applicability was considerably greater than the applicability of the present day oscillograph, which is made on the principle of the d'Arsonval galvanometer rather than the Thomson galvanometer.

I am quite aware of the fact that there are very serious difficulties with the original Blondel oscillograph, and on account of those practical difficulties, that form of instrument was set aside in favor of the one which is now universally considered. But I want to point out that somebody in the light of present knowledge and of present developments might be able to develop an oscillograph of the multiple-turn type which would still further enlarge the field of this already very powerful instrument.

The cathode-ray oscillograph, of which a very interesting type with a hot cathode has recently come out, will do this thing, because it can use separate coils, and it is also capable of operating on the principle of electrostatic deviation. But, as we all know, this type of oscillograph suffers from certain other disadvantages which are of a great deal of importance in many applications. So that the cathode-ray oscillograph cannot be said to be in a position to displace the electromagnetic oscillograph, but rather to supplement it. As we know it is capable of portraying currents of extremely high frequencies such as are beyond the range of the electromagnetic oscillograph.

To repeat, one thing that we ought to have, if we can have it, is the electromagnetic oscillograph developed in such form that it will be sensitive to currents of very much smaller value than is the present one-turn oscillograph.

Edward Bennett: Dr. Sharp has stated that there is a need for an oscillograph of high current sensibility. It may be well to point out that if the oscillograph is to be used to obtain oscillograms of alternating currents or of rapidly varying currents its current sensibility may be increased a hundred fold or more by the use of a current transformer. Such a transformer is described in the TRANSACTIONS for 1914 in a paper entitled "A Milliampere Current Transformer." By the use of this transformer, extremely accurate oscillograms can be obtained of alternating currents having a r. m. s. value as low as 0.0002 ampere, provided this current is supplied under such conditions that a voltage drop of 4 volts across the current transformer is not objectionable. The limitations of the existing oscillographs as regards sensibility are best thought of and expressed in terms of the watt sensibility of the instruments. Thus, it requires a minimum watts expenditure of 0.2 milliwatts in the vibrator to obtain an oscillogram of reasonable amplitude.

With the advent of permalloy, it should be possible to construct current transformers to obtain oscillograms of currents as small as 20 microamperes.

C. H. Sharp: What about direct-current?

Mr. Bennett: If the current which is to be recorded is varying rapidly enough, that is, if it is not an extremely long-period phenomena the current transformer is satisfactory, although you have to make some interpretation then for the steady drift that occurs under those conditions.

L. T. Robinson: A very interesting point was raised by Dr. Sharp, with reference to the cathode-ray oscillograph, which certainly will do lots of things that nothing else will do but it sometimes fails to operate satisfactorily. In that respect, it differs from the other type of oscillograph, which is about twenty-five years ahead of it, perhaps, in commercial development.

With regard to the sensitivity of the oscillograph, it is seldom the case that Dr. Sharp is wrong, but I think in this instance he is. That is, I don't think that the earlier Blondel type is sensitive, when you think of the watt sensitivity. To be sure, it will go on a very small current, but in watts, I feel sure, that the other type is much more sensitive.

Professor Bennett's contribution about the current-transformer is all right, too, but it puts it into a less sensitive class rather than into a more sensitive class, because, however good the transformer is it must take some energy to run it.

The real way is to make use of the vacuum-tube amplifier. It is very sensitive, very effective, very easy to use, and at once you are in the microwatt class. That is, it consumes very little energy in relation to the quantities to be measured. With a properly designed amplifier it can even be made reasonably successful on direct-current.

F. G. Baum: I am encouraged to tell of the application of the oscillograph to a specific mechanical problem, because I think it will suggest the application to other problems.

A few years ago we started a water turbine under a 425-ft. head, 40,000 h. p., and when the load came on the turbine, a distinct vibration was set up in the penstock, the pipe line being about 1000 ft. long and 8 to 10 ft. in diameter. The vibration was so distinct that you could hear it several hundred feet away, and near the turbine it would break off the small pipes that were connected to the instruments. It was rather a disturbing thing to us and it occurred largely as the load came on. At light load, it occurred very little.

Mr. Roy Wilkins applied the oscillograph to this problem. I think you will find it described either in the Institute records or in the *Electrical World*, I am not certain which. He merely used a diaphragm taken from a phonograph, with a carbon element going to the oscillograph, and the vibration was found, I believe, to be about 80 cycles per second. Changes were made in the runner which changed the vibration to such an extent that the turbine was all right; it was perfectly safe as an operating problem although a slight vibration was still left.

However, it was decided that new runners should be designed and here is an application of the oscillograph to the design of a 45,000-h. p. runner of a water-wheel.

There are other applications for which we might use it. For example, on certain long spans where we pull up the wire tight, the wire at the tower is thrown into vibration. In one of our steel spans crossing the Bay of San Francisco, a span 4400 feet long, there was a decided vibration as the span approached the fixed support. That was corrected by adding weights, beginning with small weights away from the support and gradually increasing the weights as we approach the tower. But I think we could have made a better solution of the problem with the oscillograph.

I. M. Stein: The outstanding feature of an oscillograph is that it records what happens during very short intervals of time. Progress with these new mechanical and physical appli-

cations of the oscillograph will be more thorough and more rapid, if we can work with still shorter intervals, and this means a shorter period in the vibrating element. A short period is something which has to be built into the oscillograph. In other words, if the development of the oscillograph is along the line of putting into the oscillograph something which you can't put outside, leaving to vacuum-tube amplifiers the matter of getting proper sensitivity, we will get farther than by trying to get higher sensitivity inside of the instrument.

Direct-current amplification as mentioned by Dr. Sharp is very important. It would be a real service to humanity if one could improve the d-c. amplification methods; I have in mind particularly the need for a device to measure X-ray dosage in the treatment of cancerous growths. The problem involves the measurement of a minute direct current through an ionization chamber. It is only recently that d'Arsonval galvanometers have been developed to be sufficiently sensitive for this work. Such instruments are very satisfactory for investigators, but the X-ray physician needs a more rugged instrument with a good d-c. amplifier.

W. H. Pratt: One point that Dr. Sharp raised in connection with Mr. Curtis' paper (and it has been touched on also by Mr. Stein) is the sensitivity and the periods of operation. I think that Dr. Stein had in mind the Einthoven galvanometer when he made those remarks. Dr. Einthoven told me not long ago that in some of his recent instruments he was able to obtain a natural period of oscillation of the order of a million cycles per second; and the sensitivity to current is correspondingly great.

H. H. Moore: With reference to the method of measuring the speed of the film, I wish to call attention to the fact, that in addition to the greater accuracy of this method over the use of a 60-cycle a-c. wave, it is also decidedly more convenient, and in the case of a three-element oscillograph it makes available an additional element thus increasing the usefulness 50 per cent, and obviating in many cases the use of an additional oscillograph.

Recently the Ballistic Section of the Naval Research Laboratory made an investigation of the hydraulic steering gear of the *U. S. S. West Virginia* and used extensively the oscillograph and the step-by-step method of recording. This work involved the measurement of hydraulic pressures of approximately 1000 lb. per sq. in. maximum at six principal points of the system; rudder angle, ship's heading, and power input to the steering motor, all relative to time. Each individual run required about 8 min. to complete. The pressure, rudder angle and power input intervals which were approximately equal required about 40 sec.

In connection with this work it was necessary to develop considerably new equipment for the oscillograph. A film holder to take 200 feet of film and give it a uniform rate of travel at about $^1/_2$ in. per second was developed. This compatarively slow film speed required a different timing mechanism and an apparatus was devised to give flashes of light each second. Incandescent lamps were used as the source of illumination. All of the apparatus functioned satisfactorily, and it is not believed that apparatus other than the oscillograph and the step-by-step method of recording are now available which would have given the desired results.

V. Karapetoff: In Fig. 11 curves are shown obtained by a graphical differentiation of an experimental curve. It may be of interest to call attention to my integraph, based on parallel-double tongs, which permits one to draw such derived curves directly, by simply following a given curve with a stylus. The instrument is described in the *Journal* of the Optical Society of America, v. 6:978, 1922

G. W. Vinal (communicated after adjournment): Difficulties arising from the amount of current required to operate the oscillograph have been overcome in connection with a study of potential measurements and polarization at the Bureau of Standards, by the use of a resistance-coupled amplifier. The cell under examination was made a part of the potential applied to the grid of a vacuum tube. The oscillograph element was connected with the plate circuit of the second amplifying tube. With such an arrangement no current is required from the cell which is under investigation. By using a half cell, a variation in the potential of single electrodes may also be observed. A discussion of this method of using the oscillograph will appear in a forthcoming paper to be published by the Bureau of Standards.

A. Naeter (Communicated after adjournment): In the discussion following the presentation of the paper by Mr. Curtis it was stated that small transient currents might be stepped up by current transformers to make them sufficiently large for recording by means of an oscillograph. The writer desires to point out that in case the primary current contains transient terms the transformer itself introduces certain terms into the secondary current.

In a paper on "Transient and Permanent Phenomena in Electric Series Transformers" presented before the Royal Society of Canada in Ottawa on May 28, 1913, Andrew McNaughton determined from mathematical considerations and experimental data that in case of transients the secondary current is of one degree higher order than the primary current. Expressing this in physical terms, it means that the secondary transient current is distorted. In a bulletin on the "Characteristics and Limitations of the Series Transformer" issued by the University of Illinois Engineering Experiment Station, A. R. Anderson and H. R. Woodrow show as a result of their investigations that the series transformer, especially with an iron core is unreliable for recording transient or unsymmetrical currents. This bulletin agrees with McNaughton that transient currents are not reproduced exactly in the secondary of a current transformer.

H. L. Curtis: Mr. Craighead has asked concerning the type of comparator which was used in measuring the films. We have used a comparator in which a microscope is moved by a micrometer screw. The operation consists in setting the microscope on two adjacent events and reading the distance from the micrometer screw. With good quality films, it is possible to set the cross hair of a microscope on the center of a line with an accuracy of about 0.001 in. A discussion of the errors in such measurements is given in a paper referred to in foot-note 2 of this paper.

The question of film shrinkage is an important one. If the film shrinks uniformly, no error is introduced since the distance between timing lines shrinks to the same extent as the distance between the events measured. However, if the film shrinks unevenly, errors will be introduced. Some values of the shrinkage of films are given in "Notes of the Shrinkage of Photographic Films (*Journal* of the Optical Society of America and *Review of Scientific Instruments*, Vol. VII, No. 3, March, 1923) and a more complete discussion is given by Frank E. Ross, "Mensurational Characteristics of Photographic Film," *Astrophysical Journal*, pp. 181-191, April, 1924. This last paper was prepared at the Research Laboratories of the Eastmen Kodak Company and indicates that a very satisfactory film can be produced.

Mr. Craighead suggests that it would be desirable to have the timing lines reach the full width of the film. We have used such an arrangement but find that occasionally a timing line will occur at the same time as an event which is to be measured. This makes the accurate measurement of the event very difficult.

Mr. Magalhaes inquires concerning the relative speed of film that can be obtained with an arc lamp and with an incandescent lamp. With an arc lamp, we have successfully worked with a film speed of 100 ft. per sec. With incandescent lamps, we have made satisfactory records with a film speed of 10 ft. per sec. provided the lamp was used at over voltage during the time the film was exposed. The point-o-lite lamp, which is a tungsten arc in vacuo, gives about the same result as an incandescent lamp. Another source of light has been tried which is produced by heating, by means of an electric current, a tungsten wire in air until it vaporizes. The current is thrown onto the wire a few tenths of a second before the shutter is opened. This

produces a very intense light but the resulting deposit of tungsten oxide is objectionable. Perhaps this could be avoided by using a carbon filament in place of the tungsten wire.

Much of the trouble with the arc lamp is due to the poor designs which are in common use. We have had very little difficulty with the hand-feed arc lamp here described. Satisfactory automatic arc lamps have been manufactured but they are not now on the market.

Mr. Legg spoke of using a short-focus cylindrical lens. This is, of course, desirable, and should be carried out as far as possible.

When an arc lamp is used the film speed could probably be considerably increased by using a fused-quartz optical system, together with a damping oil which is transparent to ultra-violet light. Such a system has been designed and partially constructed but has not been tested.

STORAGE BATTERY ELECTROLYTES[1]

(VINAL AND SCHRAMM)

NEW YORK, N. Y., FEBRUARY 12, 1925

J. L. Woodbridge: Mr. Vinal has given us the results of a new method of studying the subject of local action in the storage-battery cell. As he states, in his paper, considerable work has been done on this problem by other methods, one of them being the direct measurement of the capacity of the cell at different times, and another being an indirect method, by measuring the evolution of gases that are given off from the plates.

Each of these methods has certain disadvantages, and probably the true picture can best be obtained by a combination of all three. The direct measurement of the capacity of the cell is subject to error and can be made only at the beginning and the end of the standing test and not at any intermediate points. Furthermore, the capacity of the cell is a very variable quantity influenced by many factors, and it is very difficult to insure that an observed change of capacity is due to the particular factor that you are studying. The measurement of gas evolution is also subject to serious handicap in getting the exact results desired. This new method, therefore, is bound to throw considerable light on the problem.

There are several factors which affect the local action in a cell; for example, the temperature of the cell, the density of the electrolyte, and the history and physical condition of the plates themselves. Mr. Vinal's work has thus far been confined, as represented in his paper, to measurement at constant temperature and at one particular density of the electrolyte. We hope, therefore, that he will be in position to continue this work and to take into account these other factors.

There is another factor which would also have a very marked effect on the local action, and that is the presence or absence of electrolytic action. Mr. Vinal's work has been done so far on the cells standing on open circuit. If current is passed through the cell, a very different set of data will undoubtedly be obtained. For example, the effects of forming agents in the electrolyte will be very different when current is passing through the plates from what they are when the cell is standing on open circuit. Also, the results of the presence of metallic impurities will be varied by the effect of electric current in depositing these impurities on the negative plate.

There is one point in Mr. Vinal's paper in connection with which I would like to ask for a little additional information. For example, in Table III, and I think in other tables, two columns are given, one showing the material added, the other showing the percentage of the impurity used. It isn't entirely clear as to whether this percentage refers to the material in the form in which it is shown in the first column or whether it refers to one element. For example, copper sulphate is given in the first column, and it is not quite clear whether the percentage of copper is intended, or the percentage of the sulphate. The same might apply to nitric acid—I presume the percentage refers to the total percentage of nitric acid.

It is to be hoped that this investigation may be carried further because the problem is a large one and the amount of useful investigation that can be done is almost unlimited.

R. L. Young: Though, not a chemist, I have found the paper interesting, in that it discloses the reasons for some commonly accepted battery practises and points the way toward safe operation.

Impurities: It is of interest to note, for example, that iron, one of the most frequent and active impurities, is not deposited on the battery plates but stays in solution, so a change in electrolyte should reasonably eliminate it from the cell. I assume it would also be necessary to replace wood separators and wash the plates.

The tests showing that certain elements are very active in the presence of copper but are practically harmless otherwise, emphasize the importance of keeping brass or copper terminals and connections free from corrosion, I would enter a plea for the more general adoption by the manufacturers of terminals made exclusively of lead alloy, or where conductivity demands copper, a more complete protection of the copper portions.

Among the harmless impurities it is very fortunate that we find sodium. The foaming action of baking-soda solution during neutralization, and its non-corrosive nature, make it ideal for general use and particularly for washing down bus bars and connections, also when necessary, walls and ceilings of battery rooms. Apparently little harm would result if small quantities of solution should accidentally drip into the cells and it might be satisfactory to leave busbars unwashed by clear water if it is not intended to repaint them at the time. I should like the sanction of the authorities to follow this practise.

Gases: I find a reference to the possible liberation of poisonous gas, stibine or arsine, when antimony or arsenic impurities are present in the electrolyte. A company, with whose practises I am familiar, has some thousands of batteries in operation, some of them having 50 or more cells of large capacities similar to those used in central-station standby service. Practically all of these batteries use antimony-lead alloy grids on both positive and negative plates and it may be expected that antimony gets into the electrolyte. We have never observed any indication of poison or other harmful effects on attendants and I would question whether this danger is not more theoretical than real. Is not the ordinary ventilation provided for reasonable comfort and to prevent the formation of explosive mixtures, sufficient to reduce the antimony hazard to a negligible amount?

Specifications: Efforts toward the establishment of recognized standard specifications for electrolyte are commendable, as they will probably tend toward the development of better quality, larger supply and possibly reduced cost. They may have to be somewhat flexible, or perhaps a series of specifications will be necessary, as I understand that the amount of any one impurity permissible may be affected by the percentages of others present. This at least is more or less the case with water for battery use and I would like to see specifications on this as well. Perhaps radio fans would be interested in knowing that New York City water is usually safe, whereas the very excellent artesian well water furnished in many suburban towns is not recommended for batteries.

In Table VIII, I would suggest that two columns be added to cover values for 1.210 electrolyte, this being the standard for many batteries in stationary service.

G. M. Howard: I would like to say a word with regard to the question of antimony and arsenic in the electrolyte.

To a man who has worked with storage batteries for years, it is rather startling to read a statement like this: "These poisonous gases escaping from the cells become a serious hazard to those using the battery."

Mr. Young has touched on that from the commercial and

1. A. I. E. E. JOURNAL, Vol. XLIV, February, p. 128.

practical end. I think all users of batteries will agree with him that there have been no cases of poisoning. Certainly we have never heard of any.

As Mr. Vinal has said, the use of antimony in the grid is almost universal. Practically all lead storage batteries today contain antimony, and that means that there is nearly always a trace in the electrolyte. Certainly there is likely to be.

We have made careful tests in our laboratories when antimony was known to be present in the electrolyte, and we have never been able to detect any in the gas. On the other hand, arsenic, if present in the electrolytic may give off arsine, but, of course, arsenic is only an accidental impurity, and is never present in sufficient quantity to constitute a hazard. The point I want to emphasize is that the normal constituent, antimony, does not form stibine.

G. W. Vinal: I would like to discuss first the point which was raised by both Mr. Young and Mr. Howard regarding the possible formation of stibine.

The statement in the paper about antimony and arsenic relates primarily to these materials in solution. It should not be construed as meaning that the use of antimony in the grids is detrimental to the battery, nor liable to be a source of danger. A careful analysis of the electrolytes taken from fifteen batteries of six different makes showed that only very small traces of antimony were present in the solution. In all cases the amount observed was less than one part in 100,000. This clearly shows that under the ordinary operating conditions the antimony used in making grids does not pass into the solution. In rare instances, however, appreciable amounts of antimony have been found in the solutions, and it is to guard against such cases that it seems well to include antimony and arsenic in the proposed specification. Manufacturers of batteries endeavor to use materials which are free from arsenic and which might give rise to the liberation of arsine. Authentic cases of the liberation of stibine appear to be lacking, although we know from chemical reasoning that the conditions do make the formation possible, at least theoretically.

In answer to Mr. Young's question as to whether the ventilation in a battery room is sufficient to take care of such gases, I think the answer is quite clearly "yes."

As to the effect of sodium in the electrolyte, our experiments show that it did not affect the rate of sulphation appreciably.

A word of caution is perhaps desirable and Mr. Woodbridge has very well pointed out the fact that several methods of experimentation are desirable to reach final conclusions. I had some correspondence, with reference to sodium, with engineers of the Prest-O-Lite Company before coming to this meeting. They are of the opinion that traces of sodium may produce deleterious effects when batteries are continuously charged and discharged. That is somewhat contradictory to results which we have obtained, and yet I think that it is a point which may very well be investigated further.

As to the matter of using natural water, I know that water in New York City is commonly used in large batteries. I think New York City is blessed. It has a very fine water supply. I have been very careful, however, not to make any definite statement about the use of natural water, because natural water varies so much from place to place, and while it may be perfectly all right to use it in one location it may be unwise to do so in another. The Bureau of Standards has often been quoted as saying that the use of natural water is permissible. As a matter of fact, we have not issued any such statement.

I believe that nitrates in small amounts, such as are considered here, gradually tend to eliminate themselves from the batteries, some passing off as gas and some being reduced to ammonia.

I want to mention again Mr. Woodbridge's comments about the combination of methods. Of course, the work which we have done gives an indication of the local action which is produced within the cells, but it is quite desirable that these results should be supported, by measurements made on the batteries under normal operating conditions. We have made a few measurements on weighing the plates, with the passage of current both charging and discharging, but that work has not progressed very far. How far we shall be able to go we cannot say at the present time, but there is a very wide field of work.

One more point about the percentage of impurities,—particularly in the case of copper: the percentage which is given in the table is the percentage of copper. The impurity was added in the form of copper sulphate, but allowance was made for the SO_4 radical and for the water of crystallization.

THE DESIGN OF DISTORTIONLESS POWER AMPLIFIERS[1]

(Kellogg)

New York, N. Y., February 12, 1925

G. L. Bayley: I would like to ask the author if it is possible to make an amplifier self-exciting, very much like a d-c. generator. Is it possible to introduce resistance in the plate circuit to give a voltage drop, and to apply that drop to the grid voltage so that the total effect would be much greater amplification.

A. V. Loughren: I wonder if the members of the Institute have ever had called to their attention just how important these limits in operating a tube really are.

At a recent radio show a well known company which sells resistance-coupled amplifiers, advertising them as panaceas for all disturbances, had a set-up in which there were two amplifiers, one transformer-coupled and the other resistance-coupled. The transformer-coupled amplifier was so arranged that when an audio-frequency input was applied to the grid of the first tube, the mean plate current increased, and the obvious inference which was brought out very strongly by the salesman was that a transformer-coupled amplifier for that reason was very hard on the battery. There was altogether too low a plate voltage in the set, of course, for the grid bias used, and the trouble was that the plate current was decreasing almost to zero on the negative half of the wave, so that when the grid was made to oscillate, the mean plate current rose. Naturally, there was distortion there; but the striking point was that at the same time they had a resistance-coupled amplifier alongside it that was operated without any grid bias, so that when a speech input was put on, the grids all drew current, and for that reason on the positive half of the wave the plate current did not increase as much as it decreased on the negative half. The mean plate current accordingly decreased and the result was that the resistance-coupled amplifier was fine for the battery; but nothing was said about distortion.

As far as experimental results are concerned, the theory is absolutely correct. Last summer Mr. Kellogg was working on this problem, and I had some work to do on it from a different angle. I found it necessary to get some experimental checks. Working on tubes of somewhat lower rating than the 250-watt tube that he describes, I got experimental verifications of the predictions of power based on the characteristic curves which were good to better than 5 per cent, and the amount of distortion produced by operating under various conditions could be checked to probably 10 per cent. The method of measuring distortion, though, isn't as accurate from an experimental point of view, because it means measuring small quantitites.

G. D. Robinson: Mr. Kellogg speaks of, I believe, "negligible" distortion. It is my recollection (I fail to place it precisely) that either one year ago or two years ago at the Midwinter Convention the statement was made that two tubes working in a push-pull circuit were good for 18 times the output of one tube singly, which, of course, does not check with Mr. Kellogg's statement about the small increase in value.

Another point: There are substantially no broadcast trans-

1. A. I. E. E. Journal, Vol. XLIV, May, p. 490.

mitters working with four modulator tubes per oscillator and probably there are substantially no transmitters working with two modulator tubes per oscillator.

In connection with that same thing, we are assured by the Westinghouse Company that it is permissible to run a certain quite observable grid current on the modulator tubes without serious distortion. That probably goes back again to: What do we mean by serious distortion or negligible distortion?

P. W. Gumaer: I wish to emphasize the importance of this subject as affecting future improvements in the quality of broadcasting and its reception. One of the limiting features in perfection of the quality of radio reception has been in the acoustic end, particularly in the connection with loud speaker. Recent developments in loud speakers have overcome that difficulty. There is now a loud speaker that has no distortion that can be detected by the human ear.

The next step in the development of perfect radio reception is now up to the electrical end. In order to reach perfection in the quality of radio reception we need, I believe, a unit of measurement of distortion and a less laborious method of measuring distortion. I do not refer to any particular frequency but to the whole range of audio-frequencies, and it is indeed a difficult problem.

D. F. Whiting: One point occurs in the first paragraph of Mr. Kellogg's paper, where he speaks about the relatively greater energy required to operate a loud speaker satisfactorily in comparison with the energy required to actuate a telephone headset. Considering as a basis for comparison the relative energy requirements necessary to produce approximately the same response in the ears for the two cases, I believe that Mr. Kellogg is somewhat more conservative in his figures than is warranted by the conditions that obtain. Instead of an energy increase of one hundred times, as he has stated, I should be inclined to further emphasize the importance of this paper by favoring an increase in the vicinity of ten thousand times in the energy that is required by the loud speaker in comparison with that necessary for the headset. This value is borne out by the following figures, expressed in transmission units, such that twenty-five transmission units below an arbitrary standard, which we call "zero level" in telephone parlance, represents about the right energy to use on a headset for persons of normal hearing, whereas an energy level of fifteen transmission units above this same standard is required for good loud-speaker reception. The difference between these two figures is forty transmission units, a voltage and current increase of one hundred times, and an energy increase of ten thousand times. Some people may be satisfied with less from their loud speakers than these figures represent, but it is my feeling with respect to them that they are easily satisfied.

Incidentally, the values which I have quoted represent the amplification derived from two stages of a good-quality amplifier, or about one and one-half stages of amplification in which less attention is paid to frequency discrimination.

In regard to the dynamic characteristics of the vacuum tubes, Fig. 3 of Mr. Kellogg's paper shows a circuit by means of which certain characteristics of the tubes may be secured, but the results obtained from such a circuit are not the true dynamic characteristics of the tubes. The dynamic characteristic is affected by the impedance through which the grid receives its charge, especially when the grid runs positive, but Mr. Kellogg has limited his considerations of the dynamic characteristic, to the effects which take place when the grid potential is negative with respect to the filament, thereby neglecting the determination of the characteristic when the grid is positive. However, the dynamic characteristic covering the whole range in which we are interested may be determined by including a resistance in the circuit of Fig. 3 between the grid and the upper point where the grid supply voltage is measured. If this resistance is equal to the impedance of the circuit normally connected to the grid, the resulting dynamic characteristic will represent the effects which occur under normal operating conditions; and, if this resistance is great in magnitude, the dynamic characteristic will change its slope as the grid runs positive, tending to run in a more horizontal direction, the degree of departure from the static characteristic being dependent on the magnitude of the included resistance. The resulting dynamic characteristic represents a more accurate depiction of the effects which actually take place in the tube when in service. Although Mr. Kellogg has taken care to point out the occurrence of this effect, the curves given in his paper do not show it and the cause of the limitation is not pictured very clearly to the minds of those unfamiliar with the subject.

In reference to the discussion centering around the push-pull form of circuit, I wish to state that this type of circuit displays its principal advantages in comparison with the more simple arrangement when conditions surrounding the tube such as have been discussed in Mr. Kellogg's paper—that is, grid and plate voltages, filament currents, impedances connected to grid and plate—are not optimum. However, under optimum or nearly optimum conditions, the push-pull circuit provides an increase in energy-handling capacity of approximately 25 per cent. Relative to what may be accomplished in other ways, this does not represent a very great increase. On the other hand, this increase in power output is gained very cheaply; for no additional apparatus or power is required and, while the amplification of the final stage may be lowered slightly thereby, this usually can be restored more cheaply in the preceding stages.

E. W. Kellogg: May I ask a question at this point? On what basis are you making comparison, on the basis of an equal amount of distortion?

Mr. Whiting: Yes.

Mr. Kellogg: Total energy of harmonics the same in the cases?

Mr. Whiting: Yes. The amount by which the energy capacity increases due to the push-pull circuit feature will vary, of course, with each individual test, with the criterion assumed for the state of full load and with the accuracy with which the conditions imposed on the tubes during the test simulate the optimum conditions for maximum output. The increase I have quoted is based on the results of a rather large number of tests obtained from many tubes of various kinds and under conditions which, to the best of my knowledge, were optimum for those tubes.

In the last sentence under the paragraph entitled "Push-Pull Circuit," Mr. Kellogg states, "As against these advantages, the push-pull circuit calls for an interstage transformer which introduces some distortion." I think this sentence should be modified to state that this comparison is made with reference to a resistance-coupled amplifier, whereas, of course, the same comment would not apply if the amplifier which he was considering in relation to the push-pull amplifier was of the transformer-coupled type already.

The second paragraph under the subject of "Reactive Loads" is exceptionally good, and I want to emphasize especially what it contains. If an amplifier is called upon to transmit good-quality speech or music currents, the maximum energy which the amplifier is required to deliver occurs ordinarily at very low frequencies; and, if the amplifier is to operate without overloading, it should be capable of carrying its maximum load at the frequencies that require the greatest energy capacity. This means that the amplifier should be designed in such a manner that the output impedances of the tubes bear the right relationship to the impedance of the load at the low frequencies where the larger proportion of the energy is likely to occur. This practise is not generally followed in the case of telephone repeaters because matters concerning line impedance termination and impedance balance are of greater importance to the operation of repeaters than is the matter of maximum power capacity.

S. Stern: I have found that, very often the number of am-

plifying stages that are found necessary, must be decreased in order to prevent feed back. This feed back is very rarely due to the inductive coupling between transformers, if the proper shielding precautions are taken. The cause when traced is usually found in the tube itself in which the grid-plate capacity is often of the proper value to act as a coupling capacity between the matched audio-tuned coils of the transformers in the grid and plate circuits. A direct remedy would therefore be to reduce this capacity but this cannot be conveniently done. However, adding capacity to the grid-plate capacity, will decrease the frequency at which feed back can occur to that below the audio range. If the capacities used for this purpose have very little resistance, no decrease in amplification will be experienced.

A detailed description of this method and also the construction of a four-stage transformer amplifier, can be found on page 460 of May 1925 number of *The Experimenter* published by the Experimenter Publishing Co. of New York City.

E. W. Kellogg: Since the paper was written, my attention has been called by Mr. John C. Warner of General Electric Research Laboratory, to advantages in using a set of plate current vs. plate voltage curves to show the tube characteristics, instead of plate current vs. grid voltage as used in the paper. The two sets of curves give the same information. Thus the curves of Fig. 1 herewith are derived from Fig. 2. of the paper. When plate voltage is used instead of grid voltage for the abscissas, the dynamic characteristic for a resistance load becomes a straight line whose slope corresponds to the load resistance. The 5000 ohm dynamic characteristic shown on Fig. 1 herewith is the equivalent of Curve I of Fig. 2. Different values of load resistance, plate voltage and grid bias can be tried and compared very quickly on such a chart as Fig. 1.

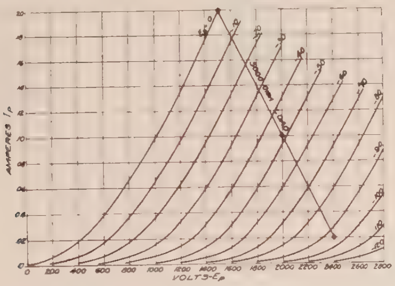


Fig. 1
Alternative Method of Showing Dynamic Characteristics

If the mean plate voltage, E_o, the load resistance, and minimum current are given, we first find the slope from the value of load resistance, then slide a straight edge, maintaining this slope, until we find a position at which the grid voltage for the minimum current is twice the grid voltage corresponding to the intersection with the mean plate voltage line. Thus the dynamic characteristic shown in Fig. 1 crosses the horizontal .02 ampere line at $Eg = -96$ volts (interpolation) and it crosses the vertical 2000 volt line at $Eg = -48$ volts. Using the approximate method given in the paper for estimating distortion, the information is conveyed readily by Fig. 1, distortion in the case of Fig. 1 being shown by the fact that the point on the dynamic characteristic corresponding to mean grid voltage is not at the middle of the characteristic.

While the use of plate voltages as abscissas makes the resistance load dynamic characteristic a straight line, it does not make a true elipse of the characteristic for a reactive load. For a general understanding of what takes place and for estimating both the kind and amount of distortion, the form of curves used in the paper is to be preferred, since the evidence of distortion is presented to the eye in much more striking form and it is at once evident whether the bend in the characteristic is approximately uniform or is abrupt. On the other hand, for rapid calculations, the second method has a great advantage.

There were a few questions brought up on my paper. The first was whether you could make an amplifier work something like a d-c. generator, self-excited. If I understand the question, it was whether we could use feed back to get more amplification without distortion (I am putting this into language that is more familiar to radio fans). I have never tried in any thorough way to do it and I don't know what the possibilities are. I can say, certainly, that it is pretty difficult and it is questionable whether it is really desirable. It is so easy to get all the amplification you need in the regular way that it hardly seems worth while to go to the difficulties that you encounter with feed back when you try to make the feed back aperiodic.

The question was brought up as to the number of modulators. I was somewhat surprised when I began making calculations on the subject to find how the case stood. I think it is no doubt true that a good many stations do not employ more modulators than they have oscillators, and I think they ought to. Of course, that is tied up with the question of how heavy modulation is being attempted. That subject is discussed in the paper. It is a debatable question how deep modulation is desirable. But the point I wanted to bring out was that if you are going to attempt to use as heavy modulation as is very commonly employed, and considered by many to be desirable, then you need plenty of modulator capacity. It isn't my purpose to say how many modulator tubes are needed, but just to speak of an excess, for the purpose of calling attention to the fact that you need to study the tube characteristics and the oscillator impedance and to find out just how many you do need.

As to working the grids positive, there are possibly cases where it can be done to advantage, by suitable circuits you might reduce the distortion introduced in that way to as low a limit as is necessary, but the task is not simple. In Fig. 2, for example, I have plotted the grid current to the same scale as the plate current, and if you figure out the resistance corresponding to the slope, you will find that by the time you have the grid 20 volts positive, which won't extend your range very much, you are down to a grid impedance of 2500 ohms, which would be a heavy load on the plate of the preceding tube, with which you are trying to push the grid. The curves as I have plotted them don't turn over, because my abscissas are grid volts, regardless of how much current I may have to supply to get the grid voltages. Mr. Whiting has suggested a way of plotting the curves, which will take into account the effect of the grid load, and make apparent the distortion which results from trying to push the grid positive.

I accept Mr. Whiting's correction of my figure for the ratio of input to telephone and loud speaker. It was merely an illustrative figure and I probably put it very mildly.

ANOTHER NEW SELF-EXCITED SYNCHRONOUS INDUCTION MOTOR[1]

(Fynn)

New York, N. Y., February, 9, 1925

C. F. Scott: The motor described by Mr. Fynn appears a sort of an extension of the motor described by Mr. Weichsel, probably with improved performance, but with some sacrifice of simplicity in construction.

Both are excellent from the standpoint of the inventor and designer, but after we get through with it all, what is it good for? It is good for improving power factor. And is it worth while to improve power factor? Is it worth while to the customer? Should he pay more for a motor in order to get a higher power factor? What he wants is power output. To make a less simple or more expensive motor attractive to him there must be inducement. That inducement probably must come through better rates for service or other advantages. Then comes the question as to whether this is the best way to improve power factor:—

1. A. I. E. E. Journal, Vol. XLIV, February, p. 164.

there are condensers of one kind or another and there are other types of synchronous motors and so on. The best way will probably again depend upon the size of motor, and conditions of the particular supply circuit, and the like. So we encounter a large and complicated economic and commercial problem of what is the right and best thing to use in different cases.

But from the standpoint of electrical engineers and of new developments in the art, it seems to me that both of these motor papers can be commended as a splendid move toward overcoming certain difficulties. Their successful application will depend on meeting certain questions in the commercial field and on the inducement given for the raising of power factor by the customer.

L. M. Perkins: If you take the simple Fynn-Weichsel motor, having a single field winding, and a single set of brushes, you may obtain any type of synchronizing torque, as it is called, from the double-frequency torque having equal positive and negative maximums, to the double-frequency torque which has a zero negative with a large positive maximum, and is designated by Mr. Fynn as the continuous positive torque.

If the brushes are shifted off from a 90-deg. position with the field winding, the torque has a so-called constant component added to the double-frequency component, until the brushes reach the point where they are in the same line as the stator, winding where the constant torque has such a value that the total torque does not become negative but reaches zero. In between these two limits, there is a large range of ratios between the constant torque and the double-frequency torque. The addition of another set of brushes and another winding increases, of course, the constant torque and adds the double-frequency torque at some angle vectorally, which will increase the double-frequency torque over what it was before. The net result, however, is simply constant torque plus the double-frequency torque, which is what was secured with the simple winding. If it is desired to increase the total amount, that is easily done by changing the resistance of the field winding.

As long as the field windings, which are connected to brushes, are all in one axis it is impossible to vary the ratio between the constant torque and the double-frequency torque beyond the range of ratios that may be secured with the single set of brushes and single winding. This is true regardless of how the angle of the brushes with each other or with the field windings is varied.

V. A. Fynn: The suggestion that the theory of this machine be gone into more thoroughly will, I think, be fully met by the addition of a couple of circle diagrams. The synchronous operation of my Form 2 motor is fully discussed in paragraph four of my paper, but the circle diagrams will, no doubt, add to the value of the record. The starting and synchronizing periods are exhaustively dealt with in my paper, the former in paragraphs 5, 6 and 7, the latter in paragraphs 8 to 24 inclusive.

The presence of the two pairs of brushes shown in Figs. 3 and 9 gives the designer possibilities of varying the compounding and the synchronizing characteristics of motors of this type not available in my Form 1 motor, which is that described by Mr. Weichsel in his paper "A New A-C. General-Purpose Motor" and commercially known as the Fynn-Weichsel.

In my Form 1, there is but one set of brushes and the compounding as well as the synchronizing characteristics depend first, on the angular displacement of the axis of this one set of brushes from the axis of the conduced ampere-turns on the secondary and second, on the conduced ampere-turns per volt, in other words on the number of turns and on the resistance of the secondary winding or windings which are connected to the brushes. There are but two ways of varying the compounding or the synchronizing characteristics, one is to change the aforesaid angular relation, the other is the change the ampere-turns per volt of the secondary windings.

In my Form 2 motor, the characteristics in question can be varied by changing the angular relation between either brushset and the axis of the secondary ampere-turns, by changing the angular relation between both brush sets and the secondary ampere-turns and by changing the ampere-turns per volt of one or of both windings on the secondary. In addition, the maximum brush voltage can be made available for synchronizing without being available in synchronous operation.

Referring to the synchronous operation, let it be supposed that the brushes are located as shown in Fig. 3 and that the maximum amper-turns in winding 12 are greater than the maximum

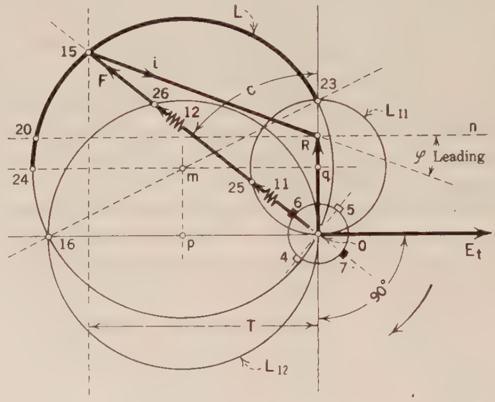


FIG. 1

ampere-turns in winding 11. To construct a circle diagram for these conditions, refer to Fig. 1 herewith and assume that R is the resultant motor magnetization in synchronous operation and that it lags 90 deg. behind the terminal voltage E_t. Further assume that R is stationary and that all the brushes, together with the windings 11 and 12 to which they are connected, are moved through 180 deg. while retaining their correct relative positions. Knowing that the magnitude of the voltage at any pair of brushes, and therefore the magnitude of the ampere-turns in the secondary winding to which they are connected, depend on the

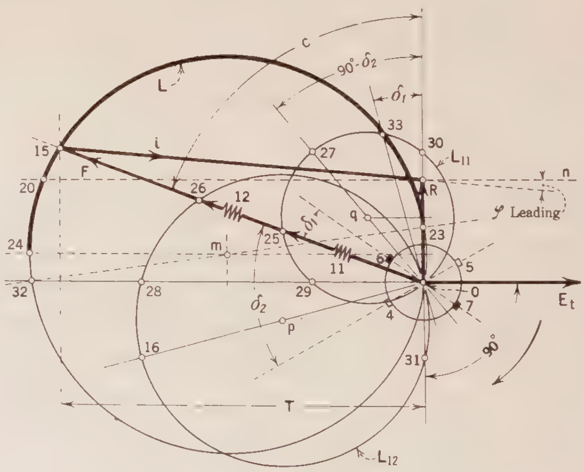


FIG. 2

angular displacement between R and the axis of said brushes, we can at once determine the positions for which the ampere-turns in 11 and 12 reach a maximum. When the axis of the brushes 6, 7 is at right angles to R the ampere-turns in 11 are zero and those in 12 a maximum. The vector 0–16 of Fig. 1 herewith shows location and magnitude of the maximum ampere-turns in 12. As the angular displacement between 6, 7 and R changes the end of the vector measuring the ampere-turns in 12 describes a circle, the center p of which is located half way along 0–16. The circle L_{12} is the locus for the ampere-turns in 12. Similarly, when the brushes 4, 5 are at right angles to R, which occurs when the

brushes have moved 90 deg. from their first position, the ampere-turns in the winding 12 are zero and those in 11 become a maximum and are represented by the vector 0–23 at right angles to 0–16. The locus for the ampere-turns in 11 is the circle L_{11} about the middle point q of 0–23 as center. But we are, at each instant, interested in the arithmetical sum of the ampere-turns in 11 and 12, this sum must always be coaxial with the windings 11 and 12 and must, therefore, be measured by a vector coinciding with the axis of the brushes 6, 7. For the angular displacement of R and the brush axes specifically illustrated in Fig. 1, the vector 0–25 measures the ampere-turns in 11, the vector 0–26 those in 12 and 0–15 is the sum of the two. The vector 0–15 represents the secondary unidirectional magnetization F. The locus for F is the circle L with center at m, which center is found as the intersection of the perpendiculars on 0–16 and 0–23 at p and q respectively. The synchronous torque T is always the projection of F on the perpendicular to S. Zero torque occurs at point 23, maximum torque is reached at point 24. The primary current i is measured by R–15 and the primary phase angle by the angular displacement of i from n which is a parallel to E_t through the end of the vector R.

Fig. 2, herewith, shows the corresponding circle diagram for a

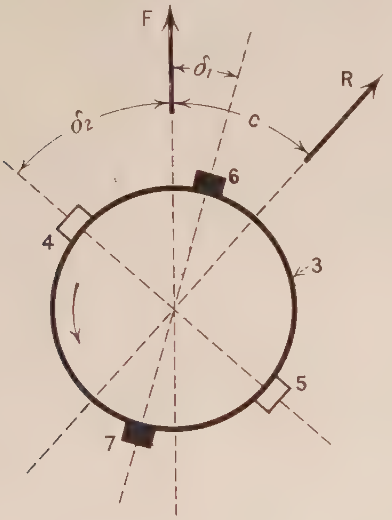


FIG. 3

case such as that illustrated by Fig. 9 of the paper. The selected brush displacements are those shown in Fig. 3 herewith and the ampere-turns per volt in the winding 11 differ from those in the winding 12. Again assuming R and E to be stationary and moving brushes and windings counterclockwise, when the latter have moved through δ_1 deg. from the position in which F coincides with R, the ampere-turns in 12 are zero. After a movement through $(90 + \delta_1)$ deg. the ampere-turns in 12 are a maximum and measured by the vector 0–16. The locus for the end of the vector measuring these ampere-turns is the circle L_{12} with center at p, midway on 0–16. After a movement through only $(90 - \delta_2)$ deg. the ampere-turns in 11 are a maximum and measured by the vector 0–27. The locus for the end of the vector measuring these ampere-turns is the circle L_{11}, with center at q midway on 0–27. To find the locus for F, which is the sum of the ampere-turns in 11 and 12, consider any two quadrature positions of the system of brushes. When F coincides with R the resultant secondary ampere-turns are the arithmetical sum of the vectors 0–30 and 0–31 of which the latter is negative. In this case F is represented by the vector 0–23. After the brushes have been moved through 90 deg. the ampere-turns in 11 are 0–29 and those in 12 are 0–28, their arithmetical sum F is 0–32. The locus for the end of the vector F is a circle L passing through the points 23, 0 and 32, which makes it easy to find the center m of this circle. For the rest this diagram is the same as that shown in Fig. 1.

My self-excited synchronous induction motor Form 2 is interesting from two view-points. It is quite independent of my Form 1, known under the trade name Fynn-Weichsel motor, and is not only capable of duplicating the performance of my Form 1 but of excelling same, for it has very useful characteristics not possessed by the latter.

THE THERMAL TIME CONSTANTS OF DYNAMO-ELECTRIC MACHINES[1]

(KENNELLY)

NEW YORK, N. Y., FEBRUARY 10, 1925

V. Karapetoff: The use of exponential expressions for heating and cooling curves of machinery is quite old. I published a complete theory of such curves in my Laboratory Notes in 1906. See also my "Experimental Electrical Engineering," second edition, Vol. II, pp. 69 to 74. For a number of years we had at Cornell a student experiment on temperature rise in transformers using and checking exponential curves. However, the discrepancy with the observed results was so considerable that we dropped the theory and left only the measurements. As a result of study of various Institute papers on temperature rise in electrical machinery, I have come to the conclusion that the exponential theory, in the simple form used by the author, is inadequate to represent the observed facts even in simple stationary apparatus, not to speak of revolving machinery. I therefore am omitting this theory from the third edition of my laboratory book.

Some attempts have been made of late to differentiate among the various surfaces of a machine in their heat emission. See in particular G. E. Luke, A. I. E. E. TRANSACTIONS, 1922, Vol. 41, p. 172; a bibliography is on p. 173. With two coefficients proposed by Mr. Luke, it is probably easier to approximate an experimental curve than with one time constant, only I would keep two separate expressions, with a finite difference of temperature between two parts of the machine, and not bunch them together.

It would hardly be wise to introduce the concept of an "overall" thermal time-constant of a machine into our Standards, or even to encourage its use, thereby creating an impression that heating and cooling curves of machines follow a simple exponential law with any accuracy, until we have more assurance of this fact. It is desirable to continue both theoretical and experimental researches with the view to finding out discrepancies with the simple exponential law for different kinds of electrical apparatus, from a simple wire to a big turbo-generator with forced draft. A somewhat more complicated law, with two or more parameters, will probably be necessary.

The value of the paper lies in (a) bringing the phenomena of temperature rise to the attention of the profession at large, in a clear and interesting manner; (b) showing the possibility of using a time constant to a base different from that of natural logs; (c) extending the previous treatment of the subject to the case when the losses in the machine are functions of the temperature; (d) calling attention to the desirability of including certain thermal constants among other characteristics of the machine.

I recently developed a theory of heating and cooling curves on the assumption of a finite variable temperature difference between the winding and the core, and hope to present it later before the Institute. It leads to a sum of two exponential terms with different parameters.

V. M. Montsinger: While I suspect that this paper, according to the subject, is intended to apply principally to dynamo electric machines, yet in several places, reference is made to air-cooled transformers and the inference is that oil-immersed self-cooled transformers are included in the subject under discussion,

1. A. I. E. E. JOURNAL, Vol. XLIV, February, p. 142.

namely, that the manufacturer give to the operating engineer the thermal time constant as a part of the regular specification, and that this constant can be determined by the methods shown in the paper, and that the binary instead of the exponential time constant be used.

Now let us see how the various methods of determining the time constant compare and apply to air-cooled transformers.

The author has, correctly, pointed out that when the copper and iron systems are thermally independent, it would not be necessary to resort to the graphical method of determining the time constant by drawing a tangent to the tested time-temperature line as shown in Fig. 3, or by plotting the deficiency temperature rise values against time on semi-log or arith-log paper as illustrated in Fig. 5.

Most oil-immersed transformers, with the exception of small units, where the windings are sometimes wound directly on the iron core, come within this class of apparatus in which the copper and iron parts are thermally independent. It has been my experience that when the weight of the materials, the losses and the final temperature rises are known, it is a simple matter to calculate the time constant and consequently be able to predict the temperature rise at any time during the change from one steady thermal state to another. If the final rise is known—and it usually is—for some given load, the final rise for any other load can be estimated by any one who is experienced in this line of work as accurately as it can be determined by test.

Before giving the method or formula which I have used, I would like to point out the conditions under which the method of plotting the deficiency in temperature rise against time and the graphical method of drawing a tangent to the tested time-temperature line hold, and where they do not hold.

In order to analyze correctly the thermal conditions in a transformer it is well to remember that the temperature rise of the windings above the cooling medium is composed of two steps which are: (1) top oil temperature rise above room; and (2) winding temperature rise above top oil. Each of these steps must be dealt with separately. I have found that if the deficiency in temperature rise of the maximum or top oil is plotted against time on semi-log paper, the points fall in a straight line, regardless of the size of the transformer and amount of oil. This method, therefore, can be used to determine either the decimal, the exponential or the binary time constants for any given load. Likewise, the deficiency of the winding temperature rise over the top oil against time can be plotted as a straight line on semi-log paper. The winding rise over the ambient, however, does not lend itself to this method unless we neglect the time it requires the winding oil to become constant. But after the temperature rise of the windings over the oil becomes constant, which usually requires from 20 to 30 min. for the average transformer the points naturally fall in a straight line which line is parallel to the oil-rise curve. The line, therefore, naturally does not go through the point of zero time. For this reason, I do not believe that this method would be entirely satisfactory when applied to the winding rise over the room temperature.

The graphical method illustrated in his Fig. 3 is really not satisfactory for either the oil rise or the winding rise over the room temperature. The temperature of a large body of oil when loss is first liberated in it does not immediately start to rise but seems to have a certain time lag. This slight displacement of the curve at the beginning is enough to prevent the drawing of a tangent to the line with any reasonable degree of accuracy. Furthermore, I do not believe that this method will give entirely satisfactory results for any type of apparatus because so much depends on the first few readings being absolutely accurate, and again, even if the first test points were right it is rather difficult for one to know just where to draw the tangent. When applied to the temperature rise of the windings over the room the method falls down completely, for the reason that, as pointed out before, the winding rise increases very rapidly at first and becomes constant within 25 or 30 min. whereas the oil required approximately the same number of hours, *i. e.*, about 25 hours to become constant. Consequently, the tangent line is too nearly vertical and gives a very much smaller time constant than the correct one. And then, there is the further objection or disadvantage to both the graphical and deficiency methods as applied to the oil rise of transformers that the time constant for a given transformer has different values for different loads. The reason for this is that the temperature rise for constant conditions is never proportional to the loss but to the loss raised to some power less than unity, generally around 0.8. This means, therefore, that it would be necessary to make a test under all the possible loading conditions which is an impractical thing to do. The same objection holds for horizontal coil rises over oil, but not to vertical coil rises over oil, because in the latter case, the rise is approximately proportional to the loss.

I believe Dr. Kennelly will agree with me that where the thermal conditions are simplified as they are in a transformer and where temperature rise is not proportional to the loss, the most satisfactory method of determining the thermal time constants is by calculating them. At least, he gives this intimation on the bottom of the seventh page and top of the eighth page.

The formula which I have used for several years with satisfactory results is similar to equation (**27**). The formula and the definition of the various factors in it are as follows:

$$\theta = \theta_f \left(1 - \epsilon^{-\frac{t}{B}}\right)$$

in which

θ = temperature rise at time t.

θ_f = final temperature rise with the resulting loss (*i. e.*, considering the increased copper loss due to increased temperature) for constant conditions.

B = Time constant

$$= \frac{C\,\theta_f}{L}$$

L = initial loss in watts

C = thermal capacity of mass being heated.

When calculating top oil temperature rise, and time t is expressed in hours:

$C = (2.96\,c + 3.5\,i + 105\,a\,G)/60$

where

c = lb. copper

i = lb. (core + 2/3 tank wt.)

G = gallons (U. S.) oil

a = ratio of average to max. vertical temperature gradient of tank (which ranges from about 0.75 to 0.95, depending on the design).

When calculating winding temperature rise above top oil, and expressing time t in minutes.

$$C = 2.96 \left(\frac{A + a}{2\,a}\right) \times \text{lb. bare copper.}$$

where A and a are the insulated and bare cross sections, respectively, of the conductor in the winding.

No attempt will be made here to compare calculated and tested results as space does not permit. However, a paper giving a more complete discussion of this subject will be published in the near future by Mr. W. H. Cooney, who is associated with me in my work.

Dr. Kennelly strongly recommends that we discard the exponential time constant and use the binary time constant. I am in accord with the author in everything he says regarding the advantages of the binary over the exponential time constant, and would be glad to see the binary constant used.

In reference to the theoretical formula, that is, equation (**47**), which he gives for the cooling after load is removed, I would like to point out that it has been found that this formula cannot be used to calculate the cooling of the windings of oil-immersed

transformers after shutdown. The reason seems to be that the temperature of the cooling medium for the windings, which, of course, is the oil circulating around and through the windings is undergoing a change in temperature at the same time the windings are cooling down. This subject was discussed fully in my paper on "Cooling of Oil-Immersed Transformer Windings after Shutdown," given in the March, 1917, A. I. E. E. JOURNAL. It was shown in this paper that the cooling of the windings was approximately a function of the watts per pound in the copper and of the time after shutdown. Even the insulation on the conductors, etc., does not have to be considered, consequently the problem is very much simplified. The rule for cooling after shutdown given in the present A. I. E. E. Standards was based on the data given in the above referred to paper. The formula is of the form:

$$\theta = 1.95\, W_c^{.7}\,(1 - \epsilon^{-at})$$

in which

θ = cooling in deg. cent.
W_c = Watts per lb. of bare copper
a = $0.106 W_c^{0.3}$
t = time in minutes.

With reference to the proposed method of correcting for a change in ambient temperature, during heat run, while I have not tried it out, I feel that the most satisfactory means of doing this for a transformer is by the use of an idle unit having approximately the same amount of material as the unit under test. While the idle unit may not always give ideal results, it appears to be the most practical at present and it is recommended that it be used wherever possible.

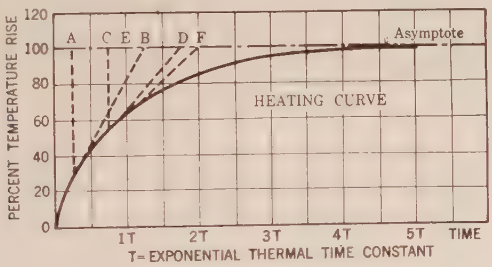


FIG. 1

In closing I would like to urge that we give serious consideration to the author's plea for the adoption of the binary time constant. There is no question but that it is preferable to the exponential constant. The fact that I advocate the method of calculating the constant for transformers does not affect in the least the question of the merits of the binary constant.

W. B. Kouwenhoven; Dr. Kennelly's paper on "Thermal Time Constants" is a valuable one, and his introduction of the "binary time constant" simplifies to some extent the use of temperature data.

I have had occasion to make quite a number of heat tests during the past several years, and I have found that the use of the theoretical temperature curves and thermal constants will often save considerable time in determining the rating of a piece of equipment. There are three principal uses to which a knowledge of these curves may be applied.

1. By means of the curve plotted from the readings secured in the first two to three hours of an eight-hour heat run, we can predict fairly closely the end temperature or maximum temperature rise that will be reached at the end of the test period.

2. By means of the same curve secured in the early part of the heat run we can determine whether we are applying the proper load for the eight-hour rating; and whether the machine will reach the specified temperature rise in the specified time.

3. We can determine the thermal constant of the machine, and as shown by Dr. Kennelly, use this in estimating what the machine will do under intermittent load or under some other load conditions.

Before discussing these applications it will be necessary to refer to the heating curve shown in the accompanying Fig. 1. The maximum or end temperature is the asymptote to this curve. It can easily be shown that the sub-tangents $A\,B$, $C\,D$ and $E\,F$ of the heating curve, referred to its asymptote as an axis, are equal.

In the actual heat run the desired load is applied, conditions being kept as nearly constant as possible, temperature readings are taken at frequent intervals and the temperature-rise curve is plotted. As soon as a sufficient length of curve has been obtained, a number of tangents to this curve are drawn and as nearly as possible, the height of the horizontal line that will give equal subtangents is determined. The point where this cuts through the Y axis gives the end temperature.

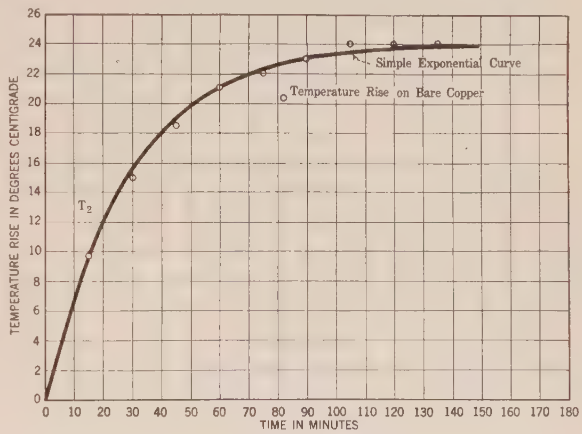


FIG. 2—TEMPERATURE RISE OF 35,000 KV-A. TURBO GENERATOR

Generator rating—12,000 volts, three-phase, 60-cycles; operating at 75 per cent load, starting from 50 per cent load at constant temperature.

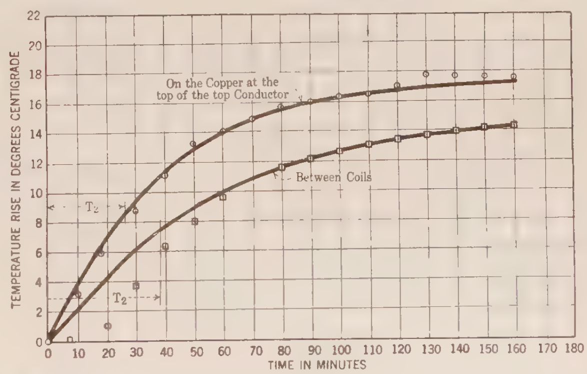


FIG. 3—TEMPERATURE RISE OF 25,900 KV-A. TURBO GENERATOR

Generator rating—8000 volts, three-phase, 60-cycles; temperature rise under 75.3 per cent load, starting from constant temperature and 45 per cent load. Simple exponential curves used to fit experimental data.

As Dr. Kennelly has shown, these subtangents are also equal to what is known as the exponential thermal time constant of the apparatus and in a length of time equal to five exponential thermal time constants the machine will reach 99.4 per cent of its maximum temperature rise. As soon as the constant is known we can not only predict the end temperature but also the duration of the heat run necessary to reach this final temperature. By this means we can tell whether the proper load is being applied for a given rating.

In using this theory in practise there are many cases where the

heat curve is of such irregular shape that it is impossible to draw tangents and to obtain any idea of the constants of the apparatus under test. In other cases the early part of the curve is useless, but the middle portion may be of value and may permit us to obtain an idea of the end conditions.

My experience, however, has been that it is always worth

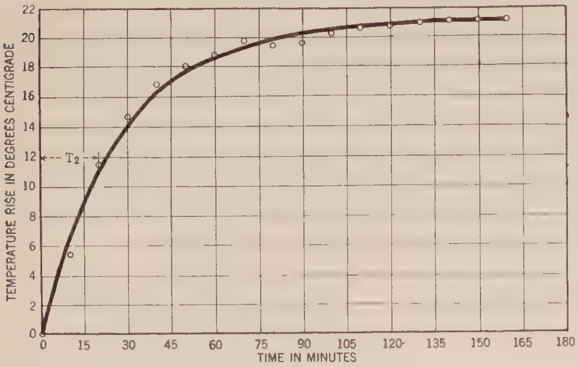


Fig. 4

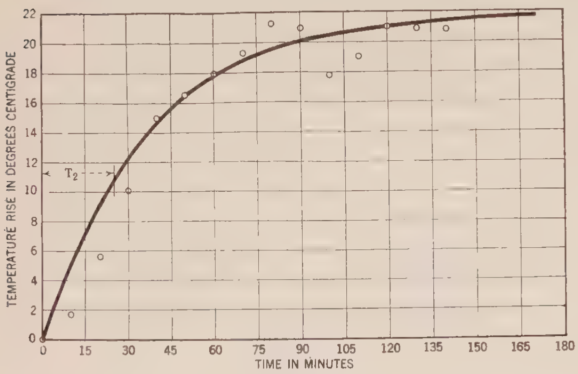


Fig. 5

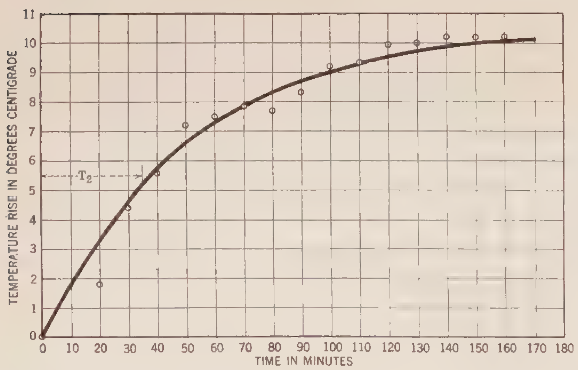


Fig. 6

Figs. 4—5—6—Temperature Rise on Various Parts of 25,000-Kv-a. Turbo Generator

Generator rating—66,000 volts, three-phase, 25 cycles; temperature rise under full load from constant temperature under 74.5-per cent load. Simple exponential curves are used to fit the experimental data.

Fig. 4 shows temperature at surface of top conductor as measured by thermocouple

Fig. 5 shows temperature between coils

Fig. 6 shows temperature of field-winding, calculated from the resistance rise

while to attempt to apply the theoretical curve in making a heat run.

C. M. Laffoon: The simple exponential relation between temperature rise and time during the transient temperature period for any given constant-load condition is correct on the basis of the simplifying assumptions which were made. As a matter of fact, this exponential relation has been well known for a number of years. Designing engineers of electrical machinery have used similarly shaped curves as obtained from test or by calculation to determine the temperature rise of machines when operating under different load conditions.

At the present time, there is insufficient experimental data available on actual machines to determine definitely how far it is necessary to extend the analysis in order to obtain a satisfactory solution. If no simplifying assumptions are made and the analysis is based on the actual distribution of the losses, and the losses are considered to be dissipated principally by conduction and convection, the solution becomes very complicated and involved. Fairly complete mathematical solutions have been worked out for the case of transformers and considerable progress is being made in determining a more complete solution for rotating machines.

The accompanying curves in Figs. 2 to 7 show the measured temperature rises of several large turbo-generators at definite time intervals when operating under constant load conditions. The temperatures of the armature windings were obtained by imbedded temperature detectors which were placed in contact with the bare copper, as well as between coil sides. The temperatures of the field windings were obtained by the increase-in-resistance method. Simple exponential curves are superimposed on the test points. It is interesting to note that the simple exponential curves practically coincide with the test points for the case of the temperatures on the bare copper. In the case of the temperature detectors placed between the coil sides, the exponential curves fit the test points reasonably closely, as the temperatures approach sustained values, but during the early part of the transient state the test points drop appreciably below the exponential curves. This temperature dip or lag is due to the fact that there is an appreciable volume of insulation through which the heat, caused by the copper loss, must flow and its coefficient of specific heat is relatively large, as compared to that of copper.

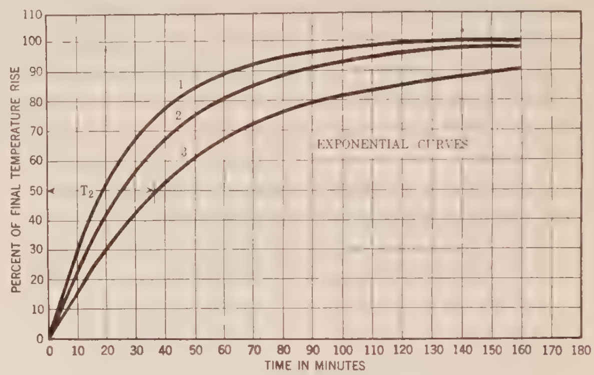


Fig. 7—Temperature Rise of Different Parts of 25,000 Kv-a. Turbo Generator

Generator rating—6600 volts, three-phase, 25 cycles, operating at 100-per cent load starting from constant temperature at 75 per cent load.

Curve 1 is temperature on bare copper

Curve 2 is temperature between coil sides of armature winding

Curve 3 is temperature of field winding

Another interesting and practical point to note for the last set of curves (Fig. 7) is that the thermal time constants are widely different for the different elements of a given generator. In the case of the 25,000-kv-a. turbogenerator, a 50-per cent change in temperature rise corresponds to a binary time constant of approximately 20 min. for the bare copper of the armature winding, 26 min. for the temperature detectors between coil sides, and 38 min. for the field winding. (The values are based on the exponential curves.) Hence, in order to determine the rating of an electrical generator when operating under overload conditions,

it is necessary to know the thermal time constants for both the armature and field windings. If exponential curves are to be used in determining the temperatures, the curves must be based on measured values obtained near the final or sustained values.

G. E. Luke: It is of special interest to electrical engineers to be able to visualize problems such as transient heating phenomena in terms of similar electrical problems. The similarity can be seen even down to the constants of the equation. Thus, the time constant in the electrical circuit is L/R and in the thermal circuit it is k/s; (L) and (k) are similar in that both represent constants of the circuit which are proportional to the stored energy. Likewise (R) and (s) both are factors proportional to the loss in the circuit.

In a previous paper[2] presented to the Institute on a similar subject, an equation of the same form as Dr. Kennelly's equation was derived, also this equation was shown in the form:

$$t = 2.3\, \tau_e \operatorname{Log}_{10} \frac{\theta_0 - \theta_a}{\theta_0 - \theta} \qquad \textbf{(27)}$$

This is the general form where θ_a is the temperature rise at start, the other constants being the same as in Dr. Kennelly's paper. This equation will satisfy any heating or cooling condition and can be easily solved with the aid of an ordinary slide rule. This equation can also be solved graphically with the use of special nomographic charts.

An interesting application of these heating equations is in the solution of the heating problem where a continuously applied heating and cooling cycle is found. Such a cycle is common in elevators, hoists, street cars, etc. Thus the curve in Fig. 8 herewith gives a typical cycle where one load is applied at alternate intervals of (t_1 — hrs.) and another load for the other (t_2) intervals. θ_0' would be the continuous temperature rise if the first load should be applied continuously and θ_0'' the rise on the basis of a continuous application of the second load. The two points of interest on such a load are the maximum steady rise θ_{max} and the minimum rise θ_{min}.

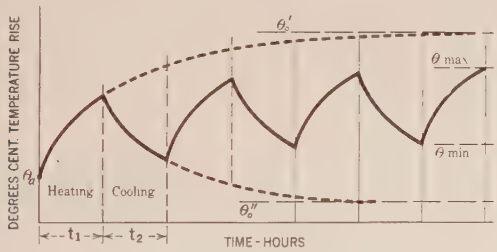


Fig. 8—Temperature Cycle of Motor on Variable Load

It can be shown that

$$\theta_{max} = \frac{\theta_0'\,(1 - e^{a_1}) + \theta_0''\,(e^{a_1} - e^{a_1 + a_2})}{1 - e^{a_2}}$$

$$\theta_{min} = \frac{\theta_0''\,(1 - e^{a_2}) + \theta_0'\,(e^{a_2} - e^{a_1 + a_2})}{1 - e^{a_1 + a_2}}$$

where

$$a_1 = -\frac{t_1}{T_e'} \text{ and } a_2 = -\frac{t_2}{T_e''}$$

if

$$a_1 = a_2 \text{ and } \theta_0'' = 0$$

Then

$$\theta_{max} = \frac{\theta_0'}{1 + e^{a_1}} \text{ and } \theta_{min} = \frac{\theta_0'\, e^{a_1}}{1 + e^{a_1}}$$

As mentioned in the paper, the heating of various parts of an electric machine is not uniform, and much of a machine's masses absorb very little heat. Thus in Figs. 7 and 8 of the paper if the time constant is calculated on the basis of the total weight of the motor its value will be over twice the tested value. On the other hand, if the heating curve for the d-c. motor armature copper is calculated its time constant will be considerably less than that shown on Fig. 8. Hence the use of such heating curves and formulas for industrial motor applications may be dangerous unless they are based upon that part of the machine that has the smallest time constant, that is, heats up the quickest.

A good example of the way various parts of a motor increase in temperature is shown on in the accompanying Fig. 9. This is the tested heating curve of a typical d-c. railway motor. Thermocouples were placed in the windings, both field and armature (with slip rings). The approximate exponential time constants based upon the tangent to the curves at the origin are 0.9, 2.1 and 2.2 hours for the armature copper, field copper, and surface respectively. The same constants based upon the time corresponding to the 63.2 per cent temperature rise are 1.1, 1.8 and 2.0 hours respectively. Thus the initial rate of heating of the armature copper is over twice the rate of the field copper. This is primarily a question of ventilation and heat flow. The time constant of the copper alone imbedded in the slots is very small, being considerably less than the values given on the author's Fig. 7 and Fig. 8. This influences the "hottest spot" and when short overload of 125 to 150 per cent of full load are found the permissible time of loading should be based upon the time constant of the "hottest spot" and not upon the average heating of the motor as found by thermometers. This point was explained in greater detail in the paper previously referred to.

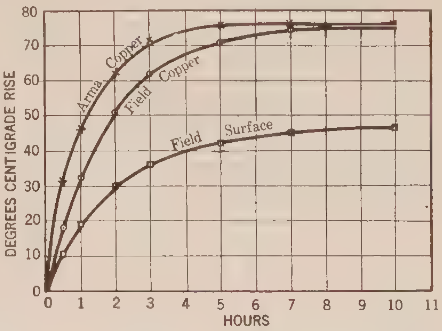


Fig. 9—Heating Curves of a 35-h. p., d-c. Railway Motor 300 Volts, 35 Amperes; Temperature by Thermocouples

It is believed that there is some typographical error in the last sentence on the fifth page, since the curve referred to, Fig. 4, is not a straight line. The equation

$$\theta = \frac{\theta_1}{2 - \theta_2/\theta_1} \qquad \textbf{(47a)}$$

holds true only if the origin is taken at the time of start ($\theta_a = 0$) and hence will not be true in general when $\theta = \theta_a$ for $t = 0$, similar to curve Fig. 3.

In the summary in the last sentence on the eleventh page, it is assumed that air-cooled transformers means oil-insulated, self-cooled, instead of air blast transformers, since the latter usually have a small time constant.

E. B. Paxton: I believe that information based on the thermal time constant as proposed by Dr. Kennelly would be very useful if it could be made available in such simple form as to be readily used and understood, not as a rating but as information supplementary to a rating.

Electrical machines could often be applied to better advantage if there were some simple means available of knowing, if only approximately, their operating capabilities under various service conditions such as, for example, low ambient temperatures or short-time operation. An understanding of what might be

2. Heating of Railway Motors in Service and on Test-Floor Runs, by G. E. Luke. Feb. 1922, A. I. E. E.

expected of a machine under such conditions would often result in the installation of a smaller machine.

A criticism has been made that each different part theoretically has its own time constant and that, due to the heat of each part affecting the others, the effect is much more complicated than indicated by the simple logarithmic relation. However, test results show, as pointed out in the discussion of Mr. Laffoon, that the temperature rises of individual parts often follow quite closely a law based on a single time constant and it is only necessary, as a basis for information to serve as a guide in operation, to regard the limiting or hottest part.

O. E. Shirley: The binary heating constant gives a very convenient method of determining to a practical degree of accuracy the heating of a rotating machine under a considerable number of varying conditions. I agree with the view brought out in some of the previous discussions that the results may vary from the actual tests under many conditions, but the method may be used to considerable advantage where approximate heating is required for machines operating on duty cycles.

A number of machines, for which heating curves are available, have been checked to obtain an idea of typical values of the binary constant. The constants for several machines are as follows:

Cycles	Kv-a.	Volts	Binary Constant (Minutes) Thermometer	Temp. Detector
25	1250	6400	30	29
25	2450	13200	38	39
25	2450	6600	23	20
50	2500	11000	25	19
60	1250	2300	15	16
60	2500	4000	20	12

The agreement between results for thermometer and temperature detector is very good except for the last machine which shows a considerable difference between the constants by thermometer and by temperature detector.

In determining the constants from the test heating curves there were some appreciable variations in the time for the different intervals, but by taking the average values for the higher increments, (*i. e.*, from ½ to ¾ rise, and from ¾ to ⅞ rise) constants could be obtained that would give curves checking the tests to a very good degree of accuracy.

The binary time constant as proposed in the paper appears to increase with the size of the machine, and also with the thickness of insulation.

The machines, which have been checked, indicate that the range of values for the usual design is 15 to 45 min., but this maximum value would very likely be exceeded in very large units and with high voltages.

As I see it, the principal advantage of the proposed constant is to give an easily remembered way of approximating the effect of a varying load from the curve of final temperature and load and the time constant which can be obtained from one test heating curve. The binary constant is very much easier to apply than the exponential constant and the accuracy of the results is the same.

A. M. MacCutcheon: This subject has a tremendous interest if we intend to use our knowledge of the time constant in connection with design and test. If it is to be given to the user of electrical apparatus for assistance in applying electrical machinery, I think it is exceedingly dangerous for the reasons that Prof. Karapetoff and others have pointed out. It is difficult to determine accurately, and it is likely to vary, I believe, even for duplicate machines. We have known duplicate machines to vary 15 degrees in measurable temperature under continuous full-load operation. If there are differences like that in machines which are intended to be identical, how can a man in the field applying electrical apparatus intelligently use a time constant if he makes its application general?

I believe that successful application of electrical machinery will result to a much greater degree if more study is given on the application problem, which is a very difficult one, and I think it would be dangerous to mislead power-apparatus users into thinking that something we can give them on a time constant is going to solve all of their difficulties. I am referring particularly to smaller sizes of power apparatus, from 250 h. p. down. When a large installation goes in possibly a time constant could be well used, because on such an installation as that, the company putting it in has high-grade engineers probably to consider the time constant and to make absolutely certain that they are applying it well. But for general applications of power motors, it seems to me extremely dangerous to attempt to give to the user a time constant which we aren't sure we can accurately predict; we aren't sure that we will not have to divide it into ten parts, as Professor Karapetoff has said, and we aren't sure that it will always be the same constant for duplicate machines.

F. D. Newbury: A possible inference from Dr. Kennelly's paper is that this mathematical relationship between temperature and time affords a practicable method of defining the rating of a rotating machine for any combination of loads and times of loading. If a machine can be given, as one of its characteristics, a single time constant, then its rating can be completely and exactly defined by stating its temperature rise at one loading, applied continuously, in combination with this time constant.

Mr. Laffoon in his discussion points out two important facts that greatly complicate this practical application: the agreement between the exponential curve and the test results is close only when it is possible to measure temperatures at or near the seat of the loss; and each machine has a time constant for each major loss-producing element. In a motor, for example, a time constant, determined from externally-applied thermometer readings, would be safe to use only when the test is continued long enough for the motor to approximate its final temperature; for short times the measured temperature is considerably lower than the temperature obtained from the correct exponential curve. In all machines of any size, and notably in turbine generators, the time constant of the armature windings and field windings will be quite different. Finally the several time constants of each size of each type of machinery will vary depending on design proportions affecting distribution of losses, heat storage capacity, and ventilation constants.

The application of this matter to the rating of electrical machinery is not as simple as it might seem from the paper under discussion, and a word of caution in connection with the practical use of the exponential relationship for the application of motors and other machinery to service conditions may not be out of place.

M. L. Keller: (by letter): Although I agree with Professor Kennelly that the binary time constant as suggested by him is the much more practical term for a simple explanation, the exponential time constant has nevertheless some importance from the practical standpoint. Instead of saying that after the lapse of one exponential time constant the deficiency is $1/2 \times 0.7182$, which for practical purposes is meaningless, we may define the exponential time constant as the time necessary to reach the maximum temperature if no heat is dissipated during the period of observation (See Fig. 10 herewith).

This definition is very simple and has also other advantages. For instance: we are able to determine the tangent of the temperature curve at the start without reference to the later period of the temperature rise.

The differential equation as set forth, is:

$$p \,.\, d\,t = G \,.\, c \,.\, d\,\theta \tag{1}$$

p = watt; G = weight (gramm), c = specific heat

Considering the temperature-rise in degrees centigrade per second of a conductor with the conductivity (ρ), specific weight (γ) and specific heat (c), at a current-density (i) amp/mm², we find

$$\theta\,°/\text{sec} = i^2 \frac{\rho}{\gamma \,.\, c} \tag{2}$$

Therefore, knowing the ultimate temperature-rise to be $\theta_0 = \frac{p_0}{s}$ (Prof. Kennelly's equations (**20**) also (**3**)), the exponential time constant is:

$$\tau = \frac{\theta_0}{i^2 \dfrac{\rho}{\gamma \cdot c}} \qquad (3)$$

This means that if we know the conductor and ultimate temperature-rise at a given current density, the value of the time constant can be easily obtained.

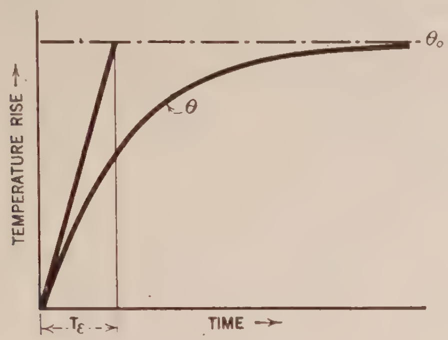


FIG. 10

Applying equation (**3**) to electrical machines, it will be found that the time constant thus determined is in most cases too small. The reason for this lies in the fact that we must take into account the thermal effect of the materials surrounding the conductor. It is apparent that the insulation around the conductor increases the time constant of the same, acting as a means of storage of heat energy produced by the conductor. It may be added that with the increase in the heat-absorption qualities and conductivity of the insulating material, the active time constant also increases. As it takes time for the surrounding materials of the conductor to absorb heat, it is evident that the increasing influence of the insulation, etc., upon the conductor depends on the rapidity of the temperature rise, which in turn depends on the load. (For load periods the duration of which is greater than about 3/5 times the full-load time constant this need not be considered.) In other words: the time constant of electrical machines is not only a function of material and construction, but indirectly also of load periods and load variations as well.

This fact is of extraordinary importance where sudden load changes in quantity and duration occur and where the total time constant of the machine is large in respect to the inherent time constant of the heat producing conductors (for instance, transformers).

The above conclusions expla inProf. Kennelly's statement, why with reference to Fig. 7 in his paper "the computed curve has the tendency to exceed the temperature curve near the middle of the run." The inherent time constant of the motor analyzed by this curve—judged by its size—will probably be half (or even less) the given full-load time constant. For a general rule, it may be said that the full-load time constant of a motor depends on the conductor plus about 50 per cent on the insulation in the slot.

Prof. Kennelly mentions as a main reason causing deviation of the temperature curve from a strict time-constant curve "that the windings of a machine with their copper losses form one thermal system and the steel structures with their iron losses, form another and that each tends to modify the behavior of the other."

This conclusion is of much importance and brings forth the question: How do these different thermal systems affect the hottest—*i. e.* critical spot—of the machine and how are we able to consider them in a simple manner? As the critical spot—which is the main point of interest to us—lies at the inner surface of the insulation next to the conductor, the simplest way seems to be, to take as a basis for any temperature consideration the time constant of the conductor which is identical with that of the critical spot and to consider the other heating sources, iron losses and adjacent conductors, as distributing factors.

Recapitulating, we may say, the smallest time constant of an electrical machine is the inherent time constant of the conductor. It increases through the thermal influence of the surrounding materials (insulation, etc.). The amount of this influence depends on the rapidity of heat changes in the conductor, this means that the time constant is also a function of the load. The heating influence of the iron losses and adjacent conductors are to be considered as disturbing factors in respect to the critical spot.

F. Wenner (by letter): In the analysis of this problem Prof. Kennelly points out the similarity between it and the variation of an electric current in an inductive circuit. This procedure enables us to handle certain parts of these two problems practically as if they were the same problem, and to apply information we may have concerning one to the other. To those who are required to work with both problems this results in a real saving of mental effort.

As this subject is one of considerable importance and the method of analysis is new it may not be out of place to point a little more in detail the way in which thermal time constants may be used to advantage in the solution of a particular problem. It will be cocneded without question, I think, that an exact mathematical solution is too complicated for general use. Further, nothing is gained by carrying the computations to four or five significant figures, since the data is reliable to a few significant figures only and the fundamental assumptions which must be made are only approximately correct. What is wanted is a simple procedure by which calculations can be made to two or at most three significant figures.

In the consideration of a similar though somewhat more complicated problem in electromechanics, it was observed that a considerable simplification could be made by using what, for the lack of a more appropriate designation, we have called a "weight" curve. This is the response and recovery curve with the time scale reversed and with all ordinates multiplied by such a factor as to make the area under the curve unity.

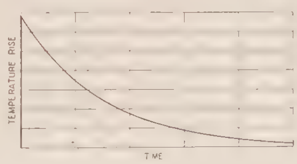


FIG. 11—TEMPERATURE RESPONSE AND RECOVERY
Load applied for an instant only

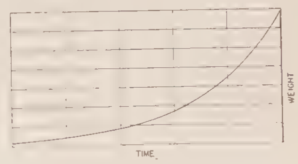


FIG. 12—WEIGHT CURVE CORRESPONDING TO RESPONSE AND RECOVERY FIG. 11

In a dynamo-electric machine heat is developed within the material of the machine simultaneously with the energy output and is dissipated slowly. If a load is applied for an instant only the mean temperature increases suddenly and then decreases very slowly following approximately a curve similar to that shown in Fig. 4 of the paper. The variation in mean temperature, therefore, may be considered to follow the curve shown here in Fig. 11. The instantaneous rise shows the response and the part beyond the peak shows the recovery. The weight curve corresponding to this response and recovery curve is of the form shown in Fig. 12. In the latter the origin of time is taken at the

end. Any convenient unit of time such as the minute or the hour may be used. However, there is a very considerable advantage in taking one of the time constants of the machine under consideration as the unit of time. When this is done both the response and recovery curve, and the weight curve are independent of the constants of any particular machine. In fact all responses and recoveries of whatever nature, which take place according to the laws assumed to apply here have the same weight curve.

If the unit of time is taken as the binary time constant then the weight at any time t is equal to $\text{Log}_e\, 2\, t^3$. This gives the following data which may be used in constructing a weight curve.

Time	Weight
0	0.693
−¼	0.583
−½	0.490
−1	0.347
−2	0.173
−4	0.043
−8	0 003

Such a curve is shown drawn to scale in Fig. 13.

Now let us see how we may proceed to predict the temperature rise for a particular machine when subjected to a particular assumed load. Let this load be as shown in the curve of Fig. 14, and let the problem be the determination of the temperature rise at the end of 4¼ hours. As Prof. Kennelly has pointed out, three specific thermal data are required. These are the ultimate temperature rise for two different constant loads and the time instant. The former give two points from which a straight line curve similar to that shown in Fig. 1 of the paper may be plotted and the latter serves to convert the time scale of the assumed load to the time scale of the weight curve. We then have three curves for use in making the calculations, namely: 1. The assumed load curve with a proper time scale, 2. The ultimate rise in temperature curve of the type shown in Fig. 1 of the paper, and 3. The weight curve as shown in Fig. 13 herewith. With these three curves, a slide rule, and pencil and paper, the calculation is carried out as follows: First, read from the load curve the average load from − ¼ to 0. Second, from the ultimate temperature rise curve read the rise in temperature corresponding to this load. Third, read from the weight curve the mean weight from −¼ to 0. The ultimate rise in temperature, times the time (in this case ¼) gives the temperature rise at the time 0 which would result from the assumed load if applied only from −¼ to 0. This figure is the first of a series to be added. Proceeding in the same way the temperature rise which would result at the time 0 from the assumed load if applied only from −½ to −¼ is obtained. This constitutes the second term of the series to be added. The 3d, 4th, 5th, etc., terms of the series are obtained in the same way, except, as the weight becomes smaller, an interval of time equal to a half, a full, or even two time constants may be used. The series is extended back so as to include the time at which the load came on, or to a time previous to which the load does not appreciably affect the temperature at the time 0. The addition of the series gives the temperature rise to be expected at the time 0 (in this case at the end of 4¼ hours) for the assumed load. The calculation is simple, straightforward, and readily gives an accuracy comparable with the accuracy of the fundamental assumptions and data based upon these assumptions.

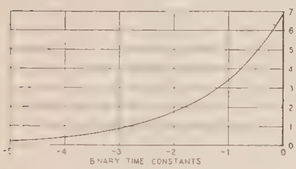


FIG. 13—WEIGHT CURVE CORRESPONDING TO RESPONSE AND RECOVERY SHOWN IN FIG. 11
Time expressed in binary time constants

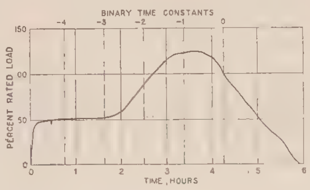


FIG. 14—ASSUMED LOAD IN TERMS OF RATED LOAD

In this discussion I have tried to show how the technique acquired in work upon a more complicated problem in electromechanics may be used in computing the temperature rise in a dynamoelectric machine, when subjected to a variable load. Fundamentally the procedure followed is the same as that outlined in the paper. It is, however, given in more detail with the hope that this may lead to a fuller appreciation of the advantages to be gained by the use of time constants, whether thermal, electrical, or mechanical, depending upon the nature of the problem under consideration.

A. E. Kennelly: The discussion has brought out many interesting and valuable points, including new mathematical material by Messrs. Luke and Wenner.

It has been pointed out that while the graphs of temperature elevations in different parts of dynamo machines may deviate considerably from exponential or time-constant curves, yet in many cases, under certain restrictions, they approximate to true time-constant curves sufficiently closely for many practical purposes. Valuable graphical data to this end have been contributed by the speakers. Moreover, it seems to be unanimously agreed that whenever a time constant can be used in practise, it should be a binary time constant.

It has been well shown that in view of deviations of heating curves from strict time-constant curves, it is unsafe to assign a time constant to a heating curve by means of a tangent drawn through the origin. Perhaps the most practical way to determine the mean binary time constant from a curve of observed steady-load heating against time, is to measure the temperature elevation θ, at successive uniform time intervals t_1. Then if θ_1 is the temperature rise in one such interval, and this has reached θ_2 by the end of the second interval, we have as the binary constant τ_2 on the assumption of exponential rise during these two intervals ($2\, t_2$)

$$\tau_2 = \frac{0.30103\, t_1}{\log \dfrac{\theta_1}{\theta_2 - \theta_1}} \quad \text{time}$$

Thus, if the chosen time interval t_1 happened to be equal to τ_2, the rise θ_1 in one such interval would be just double the further rise $\theta_2 - \theta_1$ in the second interval, and $\log \left(\dfrac{\theta_1}{\theta_2 - \theta_1} \right) = \log 2 = 0.30103$. By repeating the computation over several such successive pairs of intervals, we can easily ascertain whether τ_2 is nearly constant throughout, or whether a mean value of τ_2 can be accepted.

ELECTRICAL MEASUREMENT OF PHYSICAL VALUES[1]

(BORDEN)

NEW YORK, N. Y., FEBRUARY 12, 1925

J. R. Craighead: Mr. Borden has had a very difficult task because of the fact that it had been necessary for him to assemble a large number of methods of test, some of which border on tests of the public pocketbook rather than tests of electrical or mechanical quantity. I refer particularly to the space which he has been obliged to give to some of the more doubtful forms of mining, water, or treasure exploration and medical tests. Exploitation of the public is being made along those lines, along with the development of real means; and exploitation of

1. A. I. E. E. JOURNAL, Vol. XLIV, April, p. 363.

the medical and semi-medical fraternity is also being done to a considerable degree.

F. V. Magalhaes: From the standpoint of completeness, one other device might be placed on record to be included with Mr. Borden's otherwise complete summary of different forms of devices for electrical and mechanical measurement. A device has been developed by the General Electrical Company through Mr. C. I. Hall, Fort Wayne, which is used for physiological measurements, and insofar as the device itself is concerned, it can be considered a fairly complete development. Its application from a medical or pathological standpoint, I believe, is still under investigation.

The device is electrical insofar as the system of illumination is concerned, and it gives a record quite similar to an oscillogram, with which we are familiar. The record on the oscillogram, or the two records rather, show the horizontal component adn the vertical component of the vibration or tremor of an individual's finger. The desire from the medical standpoint, as I understand it, is to classify the tremors of the patient in the hope that they may supplement the present known methods of diagnosis. There are certain diseases that have common symptoms up to a certain point, such that they cannot be classified or identified until a succeeding symptom distinguishes the disease. It was hoped that a device that would give a picture of the amplitude, periodicity and character of the tremor of the patient might help or supplement the system of diagnosis. It would seem as if this device might properly be included in Mr. Borden's list. The device was, I believe, described briefly in the *General Electric Review* of May, 1924.

Alexander Nyman: Mr. Borden has described in his paper some methods of measuring small distances. There is quite a demand in the industry for an instrument to measure small thicknesses, say from five mils down, and the instrument that Mr. Borden described which is closest to it is the hot-wire micrometer.

This hot-wire micrometer seems to depend in its operation on heating and cooling of two coils, and naturally, an instrument like that would be quite dependent on the conditions under which it is placed. If there are any unequal air currents, the heating and cooling will not be constant.

I wonder if this same principle could not be applied equally well to an inductance or capacity change. Mr. Borden has mentioned the capacity measurement of distance, and I believe that inductance change with two coils on both sides of that meter could accomplish the results better than a heating and cooling of coils.

The instrument that I have in mind should be a compact instrument suitable for manufacturing methods, an instrument which would measure the thickness of sheets accurately and rapidly.

E. S. Lee: I want to call attention to a statement on the fourth page of Mr. Borden's paper, in the first column, immediately above Fig. 3. Previous to this, Mr. Borden has mentioned the fact that thermocouples may be used best in regions of limited area, while resistance thermometers or resistance temperature detectors are best adapted for regions of larger area. Then he says, " 'Hot spots' are better located by thermocouples placed in proximity to the windings, while average temperatures of coils may be measured by closely associated resistance units or by direct measurement of the resistance of the windings themselves."

I want to make a plea to members of the Institute to restrict the use of this term "hot spot." As far as I can find, in the files of the Institute, it has not been defined, particularly with regard to dimension.

I find that engineers in general feel that the distinguishing difference between thermocouples and resistance temperature detectors is the fact that thermocouples will measure the hot spot while resistance temperature detectors measure an average. I think you will readily agree with me that although the region of a hot spot may not be defined, the area of a thermocouple is in the order of 1/32 sq. in. If an armature coil is 10 ft. in length with a section 3 in. by ¾ in., what is the chance of placing that small thermocouple on the hottest region? While the thermocouple will measure the temperature of the hottest region if it is placed there, the difficulty of placing it there may be considerable. We don't know where to place it because we do not know where the hot region is. If we do want to establish definitely the hot region, if there is one, we have to place many thercouples all over the entire coil and get a large number of observations from which we can pick and definitely locate the hot region.

I think that the real and major distinguishing difference between the use of thermocouples and resistance temperature detectors, particularly for measuring the temperature of windings of machines, is the fact that the indicator used with the resistance temperature detector is simpler than that used with the thermocouple to give a continuous indication comparable with the indication of an ammeter, or a voltmeter, or a wattmeter.

I do not deprecate the use of thermocouples. We use them daily in our work and we could not get along without them, but I do feel that this impression which seems to exist on the part of so many, that the thermocouple will detect the hot spot or locate the hot spot, whereas the resistance temperature detector will not, should be corrected because I do not think it represents the facts.

Resistance temperature detectors can be made in small sizes for commercial instruments. They can be made in a width down to ¼ in. by 5 in. long, and if necessary perhaps smaller.

I feel that while this is not a serious statement in Mr. Borden's paper, still, inasmuch as this paper will no doubt be used as a reference because of the large number of means of measurement which he has grouped together, it would be better if that statement might be corrected, and if in the future we might make use of the correct idea rather than use this term "hot spot" without having defined it, because of the fact that one man does not know what the other man may mean thereby.

I. M. Stein: I was much interested in Mr. Craighead's remarks concerning the electrical instruments which the chiropractors are using. I agree with him thoroughly and could go much further in pointing out the ridiculous statements that are made by some of these people. The point which I should like to make particularly is that in condemning these people who are exploiting certain measurements, we shouldn't go too far and condemn those who are doing real work. I have in mind Dr. Benedict of the Carnegie Institution in Boston who has done some real work on the measurement of body temperatures, using thermocouples and a galvanometer, and he has reported his work to reputable organizations of physicians. This is really good work.

I also agree with Mr. Lee about temperature measurements in generators using thermocouples and resistance thermometers. Due to the high and uniform thermal conductivity of copper as compared with that of the insulation, I do not believe that you can count on the location of the hottest spot within 2 or 3 in., and a resistance thermometer could be made that short if it were desirable. Actually there are good reasons for making a general tor resistance thermometer somewhat longer. Therefore, I agree with Mr. Lee about the thermocouple. We find it very useful in many applications in which it excels the resistance thermometer, but I think its use in the measurement of the generator temperatures grew out of the fact that the resistance thermometer for generators wasn't very well developed at the time when the importance of generator-temperature measurements was first realized. Also, proper measuring instruments for use with resistance thermometers installed in generators were lacking. The latest resistance thermometers built by one generator manufacturer to stand the handling required

in putting them into a machine, are very dependable, and instrument circuits have been developed to eliminate the errors due to switching from one low-resistance thermometer to the next. Altogether the resistance thermometer for generator-temperature measurements is a thoroughly satisfactory device at the present time.

Copper resistance thermometers can be standardized and made interchangeable because of the high degree of uniformity of commercial copper. This is much more difficult with thermocouples because one of the elements of a thermocouple is usually an alloy and there is great difficulty in getting an alloy for making thermocouples which will match a standard curve to within one degree.

C. H. Sharp: As an example of the use of an amplifier I want to tell you of one application that we made in connection with the recent solar eclipse. At the Electrical Testing Laboratories we organized three expeditions to make photometric measurements. Besides many photometers we took a photoelectric cell connected through an amplifier to an ordinary, reasonably sensitive galvanometer, got a calibration curve of the combination against an incandescent lamp, and measured the light of the solar corona. The solar corona gives very little light. Our photometric indications and those of others indicate that it produces an illumination of between 0.01 and 0.02 footcandles. That isn't much. But the combination of photoelectric cell and an ordinary 201-A vacuum tube, and an ordinary Leeds and Northrup galvanometer gave a very satisfactory set of measurements indeed.

C. M. Jansky: Mr. Borden's paper is very interesting and instructive as it shows the application, or use, of electricity in many fields with which the electrical engineer is not ordinarily familiar. But unless we use the word "measurement" in a very loose and indefinite sense, its application to some of the detecting methods referred to is a misnomer. This is particularly true with reference to the electrical detecting methods and devices used in navigation and in the medical field. In many of these cases there is no quantitative relation determined which is the essence of measurement.

The author is undoubtedly well aware of the fact that the so-called psychological and emotional measurements used by members of the medical profession are in many cases merely a manifestation of an electrical phenomenon without any quantitative relation between the intensity of the manifestation and its cause.

In many instances the use of the electrical terminology by members of the medical profession is a mere jargon without a real physical significance. I believe this characterization applies to the attempted diagnosis employing the so-called electronic emissions of the blood.

In a paper prepared by two physicians on the use of certain electrical apparatus for the treatment of disease we find that when a patient is placed between two oppositely charged plates "he is said to be in a state of auto-condensation."

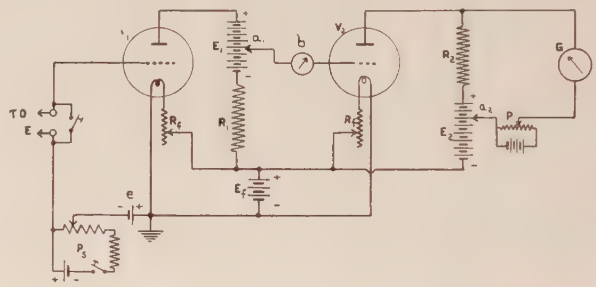
In conclusion I would like to point out that within recent years astronomers have been making use of the photoelectric cell in actual measurements, that is, in determining the relative luminosity of stars and other heavenly bodies. For these measurements, the photoelectric cell has proved to be the most sensitive device available.

E. L. Chaffee (contributed after adjournment): It may be of interest to publish a description of the direct-current amplifier which I have been using for measuring minute slowly varying potential differences which are produced in the retina of an eye when illuminated by light. This amplifier makes use of no original connections or arrangements but it is one which I have found to work satisfactorily. The connections of the amplifying system are shown in the accompanying figure.

V_1 and V_2 are thermionic amplifiers. The tubes used in this experiment are standard types made by the Western Electric Company. Tube V_1 is known as type D and has an amplification factor of about 40 and a plate resistance of 200,000 ohms. Tube V_2 is type J, and has a μ of about 8 and a resistance of 30,000 ohms. The filaments are heated by the common 6-volt battery E_f. In the particular arrangement used in these experiments E_1 is a storage battery of 200 volts and E_2 a similar battery of 100 volts. R_1 and R_2 are chosen to be at least equal to the filament-to-plate resistance of the tube with which it operates, and are 250,000 and 30,000 ohms, respectively. e is a small constant cell used to polarize the grid of V_1 to a proper negative value. P_s is an arrangement which, when the key is depressed, impresses on the grid a known small potential for calibration. The adjustable tap a_1 is attached to the battery at a point such that the grid potential of the second tube is zero or slightly negative as indicated by the absence of a deflection of the galvanometer b. G is an Einthoven galvanometer provided with an adjustable shunt. The adjustable tap a_2 is attached to the battery E_2 to that there is practically no current through the galvanometer G, perfect adjustment being obtained by means of the potential divider P. The amplification of the whole system is given in the following equation. The amplification equals the ratio of the galvanometer deflection with the amplifier to the deflection without the amplifier.

$$\mu_o = \frac{i}{e} \cdot \frac{e}{i'} = \frac{\mu_1 \mu_2 R_1 R_2 R_t}{(R_1 + r_1)(R_2 r_2 + R_2 G + r_2 G)}$$

where i is the current through the galvanometer when potential e is impressed on the grid of the first tube, and i is the galvanom-



eter current which would result if the same potential e acted in the circuit containing only the eye and galvanometer. μ_1 and μ_2 are the amplification factors and r_1 and r_2 the plate-to-filament resistances of the respective tubes V_1 and V_2. R_1 and R_2 are the respective external plate-circuit resistances as shown in the figure. G is the resistance of the shunted galvanometer, and R_t the resistance of the eye and connecting electrodes or other source of potential being measured.

A further discussion of this can be found in the *Journal* of the Optical Society, January, 1923, Vol. 7, No. 1. It is to be noted that a system of this sort gives high amplification only, and only when the resistance of the source of potential being measured is high. This can be seen from the formula given and, of course, is apparent from the fact that the vacuum tube is a high-impedance device.

Perry A. Borden: I am glad to have had Mr. Craighead and Mr. Stein further emphasize the statements that I rather cautiously made in regard to some of the electrical apparatus that is being foisted upon medical men, who know more about their own profession than they do about electrical principles. As these two gentlemen say, such apparatus is usually marked "Keep sealed;" and the same caution is generally applied to all apparatus of a kindred nature. The device for locating subterranean waters, which I made reference to, was very carefully sealed; and it was with a distinct feeling of sacrilege that I undertook to dismantle it for examination. After removing the case —a fine piece of cabinet work, by the way —and prying out a mass of solidified glue, so that the interior parts might be made visible, I estimated that such an apparatus could be made in lots of a dozen,

including the cabinet work, for about $25 each. As the instrument retails at a price, I believe, of $750, its manufacture would appear a very profitable venture.

Mr. Magalhaes suggests that I add to my paper Mr. Halls' "vibrograph," used for observing tremors, particularly in the human subject. This, I understand consists in a highly polished mirror fastened to the end of the patient's finger, reflecting a beam of light upon a sensitized surface. I should say that this device is purely optical, not in any sense electrical, and that the same results could be obtained if the light source were the old-fashioned limelight. Therefore, I question the wisdom of including the instrument in my work.

If Mr. Nyman will refer to Fig. 7, of my paper, he will see that each of the coils is very effectively protected from air currents by the cell which encloses it. There is not doubt that the principle is equally applicable to inductances or capacities instead of resistors; but in such a case it would probably be necessary to make use of alternating current in the circuit, with the attendant complications in quantitative determination of unbalance.

The remarks of Mr. Lee and Mr. Stein on my use (or misuse) of the term "hot spot" would make it appear that I have inadvertently stumbled into a controversial feature of temperature rating; and I beg to assure these gentlemen that the sense in which I wished to apply the term would refer to that point of a winding or other structure where the ratio of the heat-generating capacity to the heat-dissipating capacity would be highest. I still maintain that the general sense of my statement is correct, in that the thermocouple is the better agency for the determination of localized temperatures, and the resistance thermometer for averages.

Professor Jansky has taken issue with my use of the word "Measurement" in the title of this paper. Let me tell him in confidence that the most difficult thing in the whole work was the selection of a suitable title; and that while I might have used, as in the sub-title, the word, "Determination," I feel that "Detection" might have been too broad a term. At the same time I think it will be found that in nearly every instance which I have described, an actual quantitative measurement is performed. My statements in regard to psychological and emotional measurements have been carefully weighed, and checked against the opinions of alienists and psychologists of outstanding reputation; and I have been at great pains to differentiate between the pronouncements of the men and the "mere jargon," which, as Professor Jansky only too rightly states has found currency among some members of the medical profession. I cannot agree with the remark that psychological and emotional measurements bear no quantitative relation to the intensity of the emotion; but I will admit that these relationships are not as yet definitely known. I find that some of the best research work at present being prosecuted by psychologists, with the assistance of the Einthoven galvanometer and other electrical instruments equally sound in their principles is with a view to establishing these relationships on a sound and definite basis.

SQUIRREL-CAGE INDUCTION-MOTOR CORE LOSSES[1]

(SPOONER)

NEW YORK, N. Y., FEBRUARY 10, 1925

P. L. Alger: Mr. Spooner's paper extends by one step our knowledge of those various kinds of core losses which we have been considering for several years in Institute papers. First, we described the line-frequency losses; then, recently, Mr. Spooner described the surface losses; and now the pulsation losses are being attacked. These last losses, though, are the most complicated and the most difficult to understand of all those that occur at no load, and, consequently, it is worth while to point out some of the things that are not mentioned in Mr. Spooner's paper; which, nevertheless, are very important in this connection.

The first point I have in mind is an explanation of Mr. Spooner's statement that he finds more loss with the bars short-circuited than he can account for. I believe the reason is that when the bars are short-circuited in the rotor, the induced squirrel-cage currents shove the pulsation of flux back into the stator. That is to say, with the bars open the rotor flux pulsates; when the bars are closed the rotor flux is held constant and, consequently, the flux is forced to pulsate in the stator. Thus, losses of high frequency are produced in the stator in addition to those occurring in the rotor, and these extra iron losses account, in my mind, for the additional losses occurring beside the losses calculated to be in the copper itself.

In the second place, I will describe a convenient means of measuring the tooth-frequency losses applicable to completed machines, which Mr. Spooner has not mentioned. By measuring the running-light slip of an induction motor, the total torque developed by the flux is determined. For, the torque of the motor is proportional to the slip at light loads, and the design data give a reasonably accurate value of the torque per rev. per min. of slip. When the motor is running light, the total torque

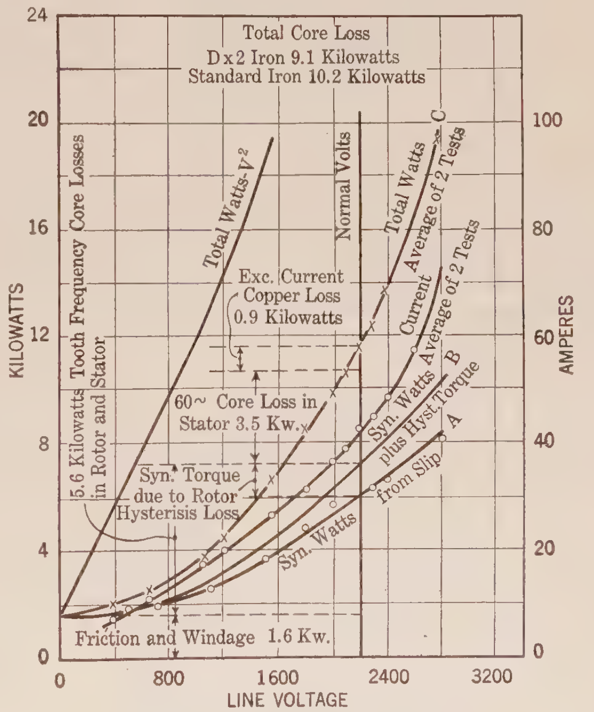


FIG. 1

developed is absorbed in overcoming the friction and windage losses and tooth-frequency losses. The tooth-frequency losses, which are due to the passage of the rotor past the stator teeth, are precisely analogous to friction losses in their manner of origin. Like all friction losses, they must be supplied from the source of power that causes the motion, which, in this case, is the fundamental electromagnetic torque of the motor. From this, it is evident that by subtracting the friction and windage watts from the synchronous torque developed by the motor when running light, as indicated by the observed value of slip, there is obtained the value of the part of the core loss due to the tooth pulsations and surface losses. The value of tooth-frequency loss so obtained must be increased by the amount of power supplied by the rotor hysteresis torque, as obtained by calculation.

The advantage of this method of measuring tooth-frequency losses is that it forms a means of segregating core loss into its two major portions as a routine part of the commercial testing. To illustrate the results obtained by the method and to make clear

1. A. I. E. E. JOURNAL, Vol. XLIV, January, p. 32.

my third and last point, there are shown herewith three diagrams illustrating the test results on three dissimilar motors. Fig. 1 shows the total core loss as a function of line voltage on a 400-h. p., 60-cycle, slip-ring motor. There are also shown curves of the synchronous watts obtained from slip measurements, and of the synchronous watts corrected by adding the hysteresis torque. With these data available, the separation of the total

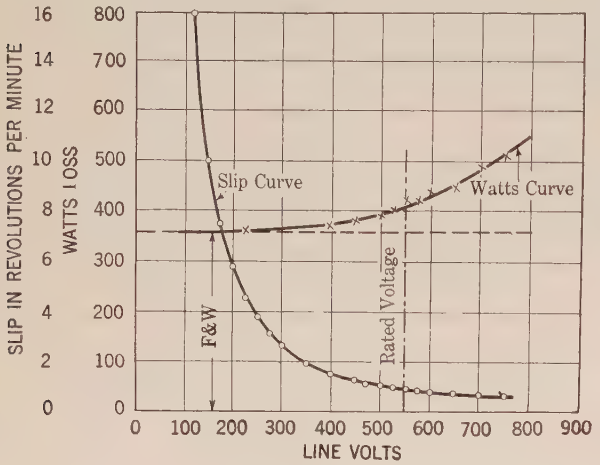


Fig. 2

loss into its components is easily made, as indicated in the figure. In this particular motor, the line-frequency core loss was only 3.5 kw. out of a total core loss of 9.1 kw., showing the motor to have an exceptionally large percentage of tooth-frequency losses.

The remaining two figures, Figs. 2 and 3, illustrate my third and last point, which is the possibility of varying the tooth-pulsation losses without affecting the major electrical character-

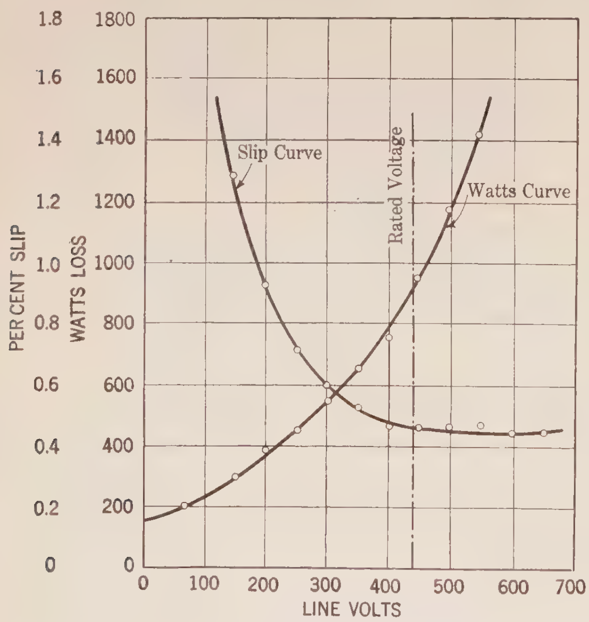


Fig. 3

istics of the machine, by varying the ratio of primary to secondary numbers of teeth. When the numbers of teeth on the two sides of the air gap are nearly equal and when the rotor slots are partly closed, each rotor tooth always spans approximately one stator tooth and one stator slot, so that its flux remains practically constant. However, when the number of rotor teeth becomes large, each rotor tooth first embraces the flux from a stator tooth, and then that of a stator slot, and so on, so that the flux pulsates very considerably. The relations to be expected between the flux pulsations and the tooth ratios are given at some length by Chapman in the *London Electrician* for August, 1916. Here it need only be said that with a large tooth ratio the pulsation losses are high, and with a nearly one-to-one ratio the losses are small.

Fig. 2 shows the running-light slip and the synchronous-watts curve on a 30-h. p. motor with 72 and 69 slots. It will be seen that the ratio of the tooth-frequency losses to the friction and windage is very small, indicating a very low total core loss. Fig. 3 shows a similar pair of curves on a 20-h. p. motor with a

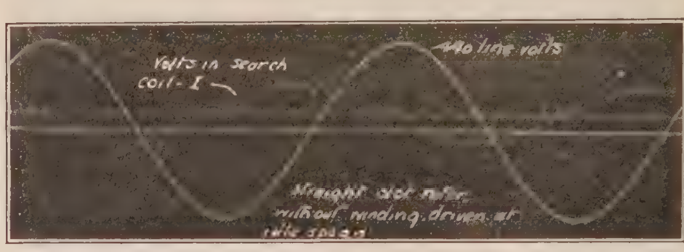


Fig. 4

comparatively large ratio of teeth, and with magnetic wedges in the rotor. This motor has a tooth-frequency core loss of five times as much as its friction and windage, corresponding to a very high total core loss.

The obvious reason for not designing squirrel-cage motors with nearly one-to-one ratios of slots and, consequently, with low core losses, is that such a design makes the machine noisy. When a combination of slots that avoids both noise and core loss is obtained, it will be found that standstill locking or synchronous crawling will occur, so that as yet no means of solving the problem other than a good old-fashioned compromise has been discovered.

H. Weichsel: Any designer of electrical machines will welcome and appreciate the valuable contributions which Mr. Spooner has given to the engineering fraternity upon several occasions on the subject of iron losses. The phenemona which are responsible for the so-called iron losses in electrical machines

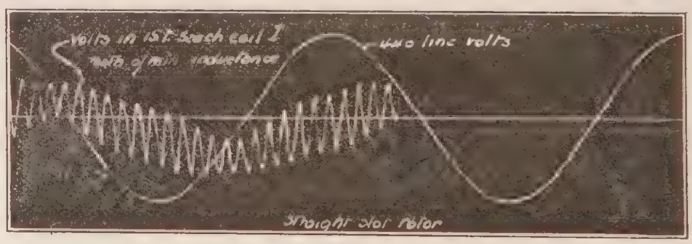


Fig. 5

are extremely complicated and are the result of a large number of factors entering into this problem. Mr. Spooner has described in various articles some of the most important factors. May I take this opportunity to point out some conditions which have not received general attention.

If a search coil is placed over a stator tooth of an induction motor and the induced voltage in this coil is recorded by an oscillogram, the following phenomena will be observed:

If the rotor is driven at approximately synchronous speed from an outside source, while the stator winding is connected to the supply line and the rotor is not provided with a winding, then certain high-frequency oscillations will be recorded, such as are shown in Fig. 4. If the rotor is then provided with a squirrel-cage winding and the machine is allowed to operate idle under its

own power, it will be noticed that the fluctuations of the voltage in the search-coil have greatly increased, as shown by oscillogram Fig. 5. This increase of the oscillations is the result of the damping currents flowing in the squirrel-cage windings.

These damping currents, as pointed out by Mr. Spooner, attempt to reduce the fluctuation in the rotor teeth. But these currents not only react on the rotor teeth but also on the stator teeth and in this latter member the fluctuations are increased. The oscillograms Figs. 4 and 5 were taken on a machine with semi-closed slots in the stator and rotor and no skew in either member.

Figs. 6A to 6C, inclusive, represent a rotor and stator punching. The stator is assumed to have open slots and the rotor is shown with semi-closed slots. In Fig. 6A the maximum possible flux will pass through the rotor tooth No. 1. In the position pictured in Fig. 6B, the number of lines passing through rotor tooth No. 1 have decreased and in the position represented by Fig. 6C, the number of lines passing through the rotor tooth No. 1 are a maximum.

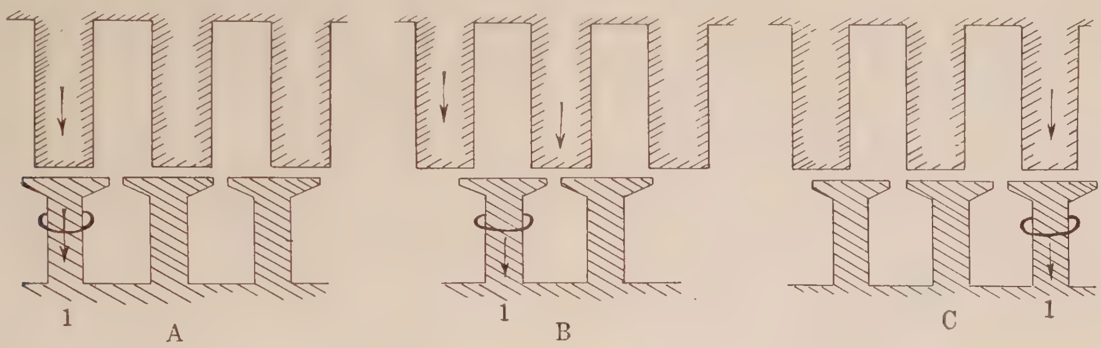


Fig. 6

A voltage will be set up in a loop of the squirrel-cage winding surrounding the tooth No. 1. The frequency of this voltage will be such that one cycle is completed during the time required for the rotor tooth to move one stator slot pitch. The current which is caused by this voltage to flow through the loop surrounding the rotor tooth No. 1 will be 90 electrical degrees displaced from its voltage. This current is a maximum when the rotor and stator tooth coincide and is zero when rotor tooth is in position *B*. (See Figs. 5 and 6.) The current is a maximum again when the rotor tooth has reached position *C*. All stator teeth which at a certain moment lie in the region of maximum induction of the main field, have the same magnetic polarity and are of practically the same field strength. During the short time required for the rotor to move one rotor slot pitch, the magnetomotive forces acting on adjacent stator teeth due to the stator winding can be considered as constant and of equal polarity and strength.

The whole arrangement pictured in Fig. 6 may be considered as a short-circuited high-frequency induction generator, where the stator forms the exciting member and the rotor coils represent the short-circuited induced winding.

At the first thought it might appear to be advisable to design the rotor punching of an induction motor with an open slot stator in such a manner that the fluctuations in the rotor teeth become zero. Such a condition can readily be obtained when the relation exists as shown in Fig. 7.

An arrangement as per Fig. 7 gives less losses than an arrangement corresponding to Fig. 8 on basis of equal induction and equal dimensions of the magnetic circuit. However, a machine built in accordance with Fig. 8 requires for the same maximum horse power less magnetic lines than a machine of equal dimensions built in accordance with Fig. 7.

As the losses decrease roughly with the square of the number of lines under otherwise equal conditions, it can be readily seen that in spite of the less favorable relations from the fluctuation point of view in Fig. 8 the total losses of the machine built according to Fig. 8 may be less than the total losses in a machine built according to Fig. 7. The general tendencies of the laws governing the relative changes between the necessary magnetic lines and the relative changes of the losses are approximately represented in Fig. 9. Experience has shown that generally the minimum iron losses for a given machine are obtained when the ratio of rotor tooth crown to stator slot pitch is 70 to 75 per cent, while the stator tooth crown is about 40 to 50 per cent of the stator slot pitch.

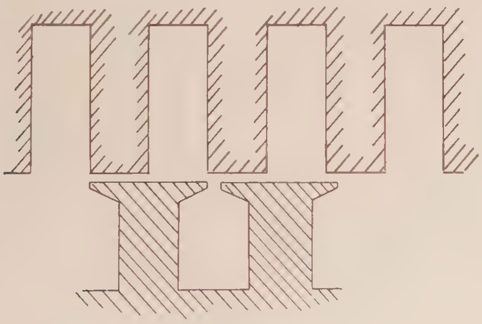


Fig. 7

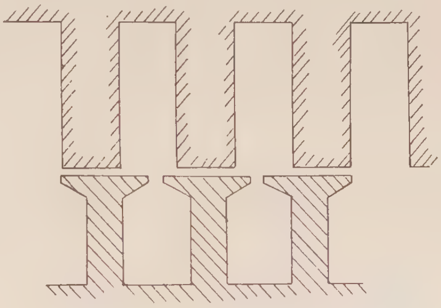


Fig. 8

It may also appear that skewing the rotor member would have a beneficial effect on the losses of a machine. It is quite readily seen that when the fluctuations in a stator tooth are of a symmetrical nature, when the rotor is not skewed, it is possible to eliminate the fluctuation in a stator tooth by skewing the rotor one rotor slot pitch. Experience has shown that a machine with skewed rotor shows a reduced fluctuation in the voltage induced in the search coil of a stator tooth. Nevertheless the idle losses of this machine are practically unchanged. This can probably

be explained by the fact that the skewing of the rotor does not influence the fluctuation of the individual stator laminations but only produces a steady flow of the total magnetic lines passing through one stator tooth. The skewing of the rotor member has further the effect of increased leakage and, therefore, for equal strength of the machine the number of lines must be increased. The only real beneficial effect obtainable by skewing the rotor is a decrease of noise and perhaps more uniform torque during starting.

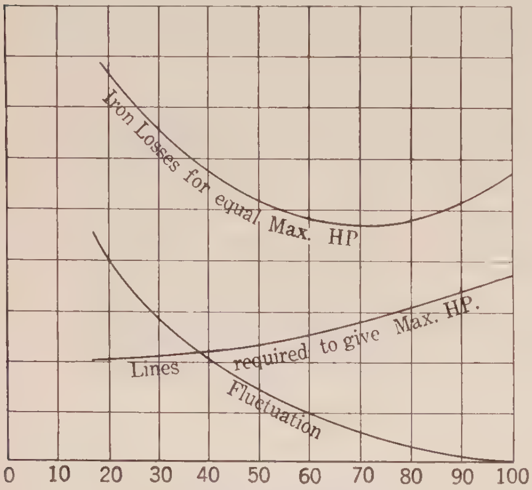


FIG. 9

The additional losses in a machine, especially the surface losses, are greatly influenced by machining operations on the magnetic circuits. Cases are known to the writer where careful reassembling of the same iron decreased the losses very materially. Other instances are known in which turning or grinding the rotor surfaces effected the losses noticeably, but it was also found that when the grinding of the rotor surface is done properly the increase in losses is negligible. The magnitude of the additional

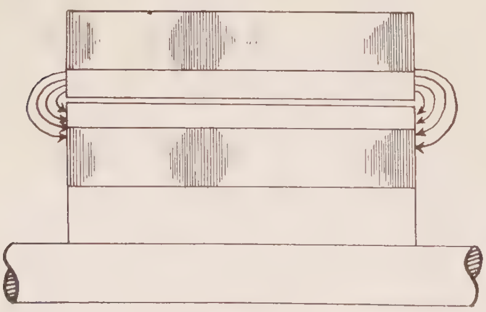


FIG. 10

losses in open-slot motors is often very large and it is not uncommon that under otherwise equal conditions open-slot motors have 1½ to 3 times the losses of semi-closed slot motors. That a large percentage of these additional losses are located in the rotor iron can readily be demonstrated by using different grades of iron for the rotor circuit. The writer is familiar with cases where a change in the grade of rotor iron has decreased the losses in an open slot machine 25 per cent and more.

Another loss which is not negligible will be found in the end punchings. There is a certain number of magnetic lines which pass from the stator, not through the air gap into the rotor but which pass out of the end punchings of the stator into the end punchings of the rotor, as indicated in Fig. 10. These lines penetrate the end punchings at right angles to the plane of the punching and, therefore, are most favorably located to produce heavy eddy currents. Similar conditions exist in regard to the end rings holding the punchings.

That these losses are not negligible has been frequently observed by the writer by comparing the iron losses of machines built with exactly the same punchings but with different lengths of iron. Invariably the machine with longer iron showed a smaller loss per inch of iron length than the shorter machine, the comparison being made for equal induction. This clearly indicates that quite appreciable additional losses must take place in the end punchings.

Thomas Spooner: Mr. Alger and Mr. Weichsel have undoubtedly given the correct explanation for the fact that the pulsation losses are approximately the same with and without the squirrel-cage bars connected by end rings, namely, in the former case the pulsations are set up in the stator teeth as a result of the high-frequency m. m. f. due to the currents in the rotor bars and these pulsations produce stator-tooth pulsation losses which are approximately equal to the rotor-tooth pulsation losses which existed with the rotor bars unconnected. This point was overlooked by us, consequently no measurements were made of the stator-tooth pulsations.

The method which Mr. Alger describes for obtaining pulsation losses in commercial machines should be very useful due to its simplicity. It was not applicable, however, to a large proportion of the tests which we made on the experimental machines which were described in the paper because much of the time the rotor windings were either not operative or not present at all.

As pointed out by Messrs. Alger and Weischel, there seems to be no way of eliminating pulsation losses in induction motors without producing other even worse effects, such as noise, dead points, etc. A further knowledge of the factors which govern pulsation losses and these other undesirable allied effects should, however, make possible better compromise designs than often have resulted in the past when insufficient consideration has been given to tooth pulsations.

Mr. Weichsel states that the minimum iron losses occur when the ratio of the rotor-tooth crown to the stator slot pitch is 70 to 75 per cent while the stator tooth crown is about 40 to 45 per cent of the stator slot pitch. We have no specific data to show whether or not this is correct. In general, however, our experience indicates that for open stator slots, other things being equal, the tooth-pulsation losses alone are less for a given per cent difference between the number of stator and rotor teeth when the rotor teeth are less in number than the stator teeth. There are some advantages, however, not connected directly with iron losses in having the rotor slots greater in number than the stator slots.

Referring to Mr. Weichsel's comments on the effects of end punchings, these extra losses due to these punchings are partly caused by the fact that these punchings are much thicker than the ordinary material and are often made of steel which is inferior magnetically. Under these circumstances the end punchings will frequently have several times the hysteresis and eddy losses which would occur in an equal volume of ordinary thin laminated material. The increased losses for the short armatures noted by Mr. Weichsel are undoubtedly also due in part to the axial components of leakage flux and consequent large eddy currents as explained by him.

Railroad Electrification

Addresses Delivered at the Aunual Meeting of the A. I. E. E. New York, May 15, 1925

ELECTRIC RAILROAD STANDARDIZATION

By Herbert Hoover

Secretary of Commerce

IT would give me real satisfaction if I were present with you tonight to participate in your discussion of this problem of such profound public importance. I consider it is of highest significance, that leaders representative of the railroads, electrical manufacturers, electric-power industry, and our engineering societies, in a spirit of public service, are cooperating to lay sound basic plans for electrification of our railroads and terminals.

The people of the nation have a great and vital interest in this. Such plans, if wisely laid, will shorten considerably the time until benefits of increase in transportation facilities from electrification can be enjoyed. Standardization, at least, in fundamentals, will facilitate the development of a coordinated electrified transportation system which will give maximum of service with best utilization of capital and labor. Failure to accomplish this preliminary standardization will result in enormous losses, which must reflect themselves in larger cost for transportation and in a reduced quality of service over what may be expected. Standardization of electric transportation equipment within the limits of agreement of a sufficient number of capable engineers will insure interchangeability of equipment between roads with consequent better utilization of locomotives and equipment. It will lower cost of manufacture of equipment, and reduce repair stocks. Simplification of standards will greatly enhance the efficiency of operation, since there will develop a uniformly trained group of railroad workers familiar with the standardized types of equipment. Uniformity in voltages, frequency, and other electrical characteristics will permit much more effective application of electric power. These are only a few of the benefits.

This standardization is important not only because of the benefits it will return, but for the large losses it will prevent. We have here an opportunity to forestall waste. This is a much more satisfactory and constructive method than to undergo the slow and tedious process of elimination of wastes once they have rooted themselves in an enormous industry. Failure to provide standards at this time will result in the adoption of a large variety of equipment which later will have to be brought into coordination with consequent waste of millions of dollars.

It is important that correlation of the electric light and power groups should be accomplished, to the end that electric energy may be brought to the railroads for electrification in sufficient quantity and with insurance of absolutely reliable service. Development of interconnected central station distributing systems, covering wide areas, makes possible a maximum utilization of our fuel and water resources and provides a pool of energy necessary for the electrification of transportation. Thus, the interlinkage will increase between two of our great public utilities, the railroads and the electric light and power industry. The development of electrified transportation and the electric light and power industry should take place with the closest of coordination between them.

The successful accomplishment of the degree of standardization which can now be properly undertaken is a goal worthy of the best efforts. In the accomplishment of this, the Institute will have rendered a public service of immeasurable value, enormous waste saving, and giving great impetus toward electrification of transportation.

ELECTRIFICATION OF RAILROADS

By Gerard Swope

President, General Electric Co.

ONE of the most important factors in making this country one and undivided, and tending toward greater solidarity in interest and thought has been the widespread development of transportation. This country is tremendously indebted to the courage and vision of the pioneer railroad builders in welding different sections of the country together. The union of East and West by solid ties of steel was a magnificent achievement, rarely if ever paralleled in the history of any country.

The very existence of our great cities and their growth depends on efficient, expeditious and economical transportation. It is almost impossible to appreciate the amount of transportation involved merely to maintain life in a city like New York. Well informed engineers report that the freight transportation requirements of a city in ton-miles have increased 3½ times as fast as its population, and modern city planning is largely a problem for meeting these conditions.

The position that the transportation system in the United States has reached, enjoying as it does the proud distinction of rendering the greatest service to the community as a whole of any in the world, is a monument and a credit to the initiative and enterprise of private undertaking.

The part that the steam engine has played in this

development is remarkable. Under the inspiration of the engineers associated with the railroads and the manufacturers, the steam engine has met the successive and seemingly insurmountable difficulties presented by moving greater tonnage at higher speeds. Our extensive transportation system has been so admirably served by the steam locomotive that we should not look for a change to another type of motive power unless there are good and sufficient reasons for its adoption. The steam locomotive will undoubtedly continue for many years in the service with which it has been so closely identified for nearly a century. Further improvements may be expected which will increase the power and the fuel economy of steam locomotives, but, however much may be accomplished in this direction there still remains the limitation of power imposed by restrictions in size of the locomotive boiler and fire box, and the inherently lower fuel economy in comparison with the modern steam electric power-station.

The problem before the railroads and the country is serving the people of the farms and cities in the most satisfactory manner by more efficient, more economical, more expeditious methods of handling the great transportation of this country. The electrical as well as all other manufacturers are vitally interested in the solution of this problem. The electrical manufacturer is not advocating electrification of railroads simply in order to sell his electrical apparatus—this would be a short-sighted policy. The electrical manufacturer as a member of the whole community to be served, and its hundreds of thousands of employees, wants the transportation system of the United States the best in the world, and the best adapted to meet the nation's requirements of service at the lowest cost. We do believe that electrification of a larger and increasingly larger portion of our railroads will meet these requirements more fully than any other change in the transportation system. A brief resumé of the reasons therefor follows:

First, the conversion of energy from coal to power is at best inefficient, but the more uneconomical and wasteful is the conversion of power on a steam locomotive in comparison with the high efficiency now developed in the large modern electric power-stations of the country. This difference in efficiency is inherent and cannot be modified to a great extent even by the improvements that have been and are being made in the efficiency of the steam locomotive. The saving of coal per year, if only one-half of the railroad mileage of the United States were electrified would be approximately 40,000,000 tons, or at the prevailing market price $120,000,000 per year. This would be a fine contribution to the conservation of our natural resources; would free human labor in the mines; would free investment in handling this tonnage and increase by more than 10 per cent the carrying power of the railroads so electrified. This part of the present equipment is now used to transport the coal the railroads themselves consume.

Second, the electric locomotive is not restricted in its capacity, as in the case of the steam locomotive, the latter being limited in power by the size of the boiler it can carry. The central station from which the electric locomotive derives its power is stationary and may have a capacity many times in excess of any number of locomotives that may be on the line at the same time. Electrification thus provides greater possibilities for handling heavier traffic more expeditiously under varying conditions of railroad operation, with less human effort and supervision and at a reduced cost.

Third, the contribution to health, comfort and safety by elimination of smoke and dirt in tunnels and city terminals is apparent. The increased money value, by reason of electrification, to the railroads themselves, to the city from increased tax assessments, and to private property owners through increase in value and consequent increase in rents, is readily seen. A striking illustration of this is furnished by the districts immediately surrounding the magnificant terminals of the Pennsylvania and New York Central railroads in this city.

Fourth, in many instances the capital expenditure for betterments on congested mountain grade divisions may be more profitably made for electrification than for the building of tunnels, construction of additional tracks and more steam engine facilities. The electric locomotive combines enormous tractive power with much higher speed which makes it most effective in increasing the carrying capacity of existing tracks. Thus, its introduction postpones indefinitely any necessity for the great expenditures that would be needed to give equivalent operating facilities with steam engines on the same mountain divisions.

Fifth, records kept over a long period of time show clearly that the cost of maintenance of steam engines is three times that of electric locomotives, hauling the same tonnage over the same division and under the same operating conditions.

Sixth, for switching and branch line service the Diesel electric locomotive and the gas-electric car are available. These consist of a gasoline or Diesel engine driving an electric generator, which in turn drives electric motors. The unit is self-contained and independent of trolley or third rail.

This briefly sets forth the advantages of electrification for railroad service over steam, irrespective of whether alternating current or direct current is utilized. Electrification with either medium has been of great benefit to the railroads, the traveling public and the community served.

There is still difference of opinion in the minds of prominent engineers as to the relative merits of alternating and direct current to meet the varying conditions of transportation service in the United States.

This difference is far less important than the difference between either and steam locomotives.

This difference of opinion exists also in the minds of engineers outside of this country. In most countries where this problem has arisen, it has been met nationally and a national solution arrived at, even in those countries where railroads were owned partly by the public and partly by the State. A few examples will be of interest. One system of electrification was adopted for all France, namely direct current and the French are proceeding with the work. In England, direct current has been adopted nationally—in Germany and Switzerland, alternating current. It would naturally be expected that the different nations in Europe would differ in their solutions of the same problem because of their traditional differences and diversity of interest. However, notwithstanding the tremendous difficulties of the present economic situation, Europe is proceeding more rapidly to solve the problem of railroad electrification than the United States. Today, the equipment is not interchangeable in the terminals of New York City and Philadelphia, although both operate under similar conditions in congested areas of great wealth on our Atlantic seaboard. Just as in this country there is a standard gage for tracks, couplers and standard brakes in order to make equipment interchangeable, so it is to be hoped that a national electrical standard will be adopted with all its attendant advantages. In peace this will allow mobilization of resources for the greatest economic development of this country and in war the most effective protection.

As the Secretary of Commerce has so clearly pointed out, one common system would save hundreds of millions of dollars in equipment, that would otherwise be wasted, and the difficulties, cost and delay of interchange would be greatly decreased.

Standardization will also effect very directly the use of the power developed by the large interconnected public utility companies—so-called superpower—and the best utilization of the power developed at the coal mines and water falls, resulting in the greater use and development of our natural resources.

Electrification is going to call for increased capital outlay, but standardization will materially reduce the amount needed and facilitate the raising of such additional capital:

First, by the greater use of the power developed by the larger central station systems throughout the United States, so that the railroads will obviate the large investment needed for power-stations running into millions of dollars, and

Second, by the use, if desired, of car-trust certificates or some similar plan to finance the purchase of electric locomotives. These being interchangeable for all roads will be much more easily and cheaply financed.

It is to be much desired and hoped that the railroad executives, intrusted as they are with the custody of more than $25,000,000,000 of railroad property, owned by millions of people throughout the United States, and used by many more, will approach this problem from a national and American standpoint, in order to determine the best standard and interchangeable equipment to meet the varying conditions.

Personally, I have the greatest confidence that this problem will be solved as the railroad problems in the past have been so ably and patriotically solved. To that end I am happy to pledge the assistance of the great organization with which I am associated, irrespective of individual opinion and solely from the standpoint of national interest. Whatever system is adopted, we stand ready to give the best engineering and manufacturing service that we can render to the railroads of America.

STANDARDIZATION IN ELECTRIC TRANSPORTATION EQUIPMENT

By Paul S. Clapp

Department of Commerce

It is more than proper that representatives of the railroads, electrical manufacturers, power companies, and our national engineering societies jointly undertake at once *certain standardizations* in electrical railway equipment. Such standardizations will not only facilitate electrification and provide better transportation at less cost, but will definitely forestall losses that will otherwise mount to enormous proportions in the future. The accomplishment of these standardizations is a *public obligation* of the highest importance.

Electrification of transportation requires the closest of cooperation and coordination between the railroads and the electric light and power industry. Both of these are public utilities, to whom the people of this country have intrusted the operation of the most vital functions in our national life—transportation and power. This is an expression of great public confidence. This trust carries with it the obligation to secure maximum utilization of natural resources, and to provide service of high quality with the best use of capital and labor. It certainly carries an obligation to plan the best possible electrified transportation system and to prevent by some degree of standardization, the costly wastes which will otherwise ensue.

The exact details of what standardizations are possible and desirable at this time, can only be determined after careful study by competent groups. There is no implication in this that designs will be crystallized at their present status and progress retarded. We refer to the determination of certain fundamentals which will be accepted as standard by the manufacturers and purchasers of electric railway equipment. These will embody the best thought and experience of our age and serve as guiding principles in the development of electrified transportation.

The adoption of such standards will insure future interchangeability of equipment between roads, thus increasing the utilization of locomotives and equipment. Any locomotive will be able to travel over the entire

system. The concept of a patch work of railroad mileages with a variety of electrical characteristics or contact systems *limiting* locomotive movements within prescribed limits spells inefficient operation. Such a system lacks flexbility. It prevents continuous movement of trains. It is wrong from the standpoint of national defense. One design may have advantages on a particular railroad; another design on a second. The advantages accruing to an individual railroad will be many times offset by the losses to the country as a whole.

We assume electrification of *present* steam lines and terminals. There will be but little shift then in the location of the transportation channels to be electrified. Standardization will greatly assist the power industry in the formulation of *its* plans, to provide in advance, adequate and reliable power supplied for this electrification. However, the industry will know before electrification occurs at what voltages and frequencies, delivery must be made. If they serve several railroads, the equipment to effect delivery will have the same characteristics. The points of contact between the power industry and transportation will have more uniformity. Standardization will make possible more direct application of electrical power, with minimum losses from conversion. All this means less complexity in equipment, decrease in initial cost, and lower operating costs.

Standardized equipment will come to be understood by railroad workmen all over the country. We shall, thus, improve efficiency of labor in railway operation, and there will grow up uniformly trained railway groups familiar with this standardized equipment.

Failure to effect preliminary standardizations, will not only deprive us of these benefits and others, but it will also result in enormous and cumulative losses both in cost of equipment and operation.

Diversity in sizes, dimensions, types, and styles, increases cost of manufacture. This variety works against quantity production; slows down production and delivery; complicates the procurement of raw materials; increases investment in raw stocks, work in process, and stocks of finished items; ties up more money in tools, dies, jigs and fixtures; adds to engineering expense in design; interrupts continuity in production; decreases labor efficiency. These items represent waste which must be added to cost of the equipment.

In addition, failure to adopt such standards will increase cost of operation. Larger stocks of repair parts must be maintained; longer delays from inability to get these parts will occur; out-of-service costs are higher; continuity of train operation over long runs is broken; more locomotives are needed; expensive delays in handling traffic occur; labor efficiency is less; cost of energy is increased.

The magnitude of these losses cannot be accurately predicted. We do know that they would be enormous. Australia must spend nearly a billion dollars to convert her 21 different railway gages to a common standard. Careful engineering surveys of basic industries show that wastes, largely due to excessive variation in product, amount to 30 per cent of cost.

This waste can be prevented only by standardization before any further large scale electrification takes place. Continued delay will result in these wastes becoming more deeply rooted in the whole system. Prevention of them by prompt but carefully considered standardization is an action which the public can rightfully expect.

THE FUTURE OF RAILWAY ELECTRIFICATION

By E. M. Herr

President, Westinghouse Elec. & Mfg. Co.

It is generally recognized that adequate and efficient rail transportation is the prime necessity of modern civilization. Owing to the extent of our country and the fact that we have no internal water routes of moment, the importance of rail transportation here is accentuated so that the statement as to its necessity is more correct with us than in Europe. It is, therefore, of the utmost importance that the railroads of the United States keep pace with the requirements of the future growth and development of our country. This can only be done by the adoption and proper utilization of the best and most modern machinery and methods.

During the late war the orderly progress of the railroads was interrupted. Owing to military necessities, government control and operation, not only halted the best development of our transportation systems, but the change in management and resulting disorganization of operation caused an interruption of progress and improvement which has required years to overcome, and from which the railroads are only now beginning to emerge.

Public sentiment, long antagonistic to railroads and their improvement and development, has now changed and a spirit of fairness toward the railroads and recognition of the great importance of good transportation for the best development of our country, are beginning to be shown by the public generally.

The membership of your Association are in an admirable position to be of distinct help in this situation. They are, by training, by contact with industry, and by powers of expression, able to voice a correct understanding of transportation needs and its effect upon our civilization. This should be their duty and is their obligation; and each may well ask what he himself is doing, for it is only through enlightened public opinion that progress in transportation can be secured.

During the period of the lag in railroad progress caused by the war, other methods of transportation were unduly stimulated, bringing self-propelled vehicles of many kinds into fields of transportation, legitimately belonging to the railroads. I say "other kinds of

transportation" were unduly stimulated because magnificent roads were furnished vehicular traffic at the public's expense. These roads are also maintained for the free use of self-propelled vehicles, practically by public funds since only a nominal license fee is charged. This will not continue indefinitely and when an adequate charge for the unusual use of the public highways is put upon these vehicles, many will find it unprofitable to continue. Transportation by heavy trucks has established a service, however, that will undoubtedly have to be met by the railroads. The truck calls at the shipper's warehouse for his freight and delivers it to the warehouse of the consignee, thus, for less than carload shipment, completing the transport to ultimate destination. The cost of handling freight from the customer's warehouse to the railroad terminal by the present unorganized method is a very large proportion of the cost of the rail haul itself—this business can be done by the railroads, thus securing for them an additional source of revenue. A fleet of trucks at each terminal of a railroad would enable as good service to be given by the railroads and, if combined with quick train service for all except very short hauls, more prompt deliveries could be made and with greater economy. All of this may be said to be outside the scope of an electrical manufacturer but my rather long railroad service in former years must be my excuse. And now, what of electricity in railroad service.

Electric locomotives require much less servicing, will work as efficiently in tunnels, subways, sheds or other enclosed places as in the open, and will permit of a much quicker and more efficient handling of cars in terminals than is possible with steam. Also, if the property on which the switching and terminal tracks are located is depressed, it can be used for buildings almost as well as if the terminal did not exist. In any event, the absence of steam, smoke, gases and noise, as well as other objectionable features incident to steam operation, permit the location of such terminals near high class residence or business property.

Again, terminals and yards in large cities or congested places, can be worked so much more efficiently by electric operation that much space can be saved and valuable real estate reclaimed for other uses.

The suburban traffic can not only be more efficiently handled by electric operation but the service rendered becomes much more agreeable to the road's patrons and can generally be considerably expanded with existing track facilities.

The terminal and short haul traffic, it is seen, is now a pressing and urgent matter but has been so completely and satisfactorily worked out in well-known ways that it presents no new technical problems to either the engineer or the electrical manufacturer.

What can be said about main line and heavy long-distance traffic? In this field, while the amount of work actually done during the past ten years has not kept pace with the electric-power development in the lighting and industrial fields, steady and continuous technical progress has been made. No matter what the engineering requirements may be, engineers and manufacturers are abundantly prepared to carry out the most ambitious electrification projects promptly and with assured results, for there have been numerous examples of many kinds of electrification, located not only in different parts of this country but all over the world. No system of electrification has been found impossible of successful results. The particular system to be adopted in any special case is a matter of engineering study and determination but when decided upon, there is more than one thoroughly competent manufacturing company ready to bid on and execute the work.

It is interesting to review briefly the railway electrification work already done in the world; it will surprise many that the United States is not the leader in either the number of electric locomotives in service, or in their total h. p. capacity. As tabulated in a paper by Mr. F. H. Shepard before the American Railway Association at Atlantic City June 13, 1924, the following summary gives a picture of the situation:

At that time there were built or building a total of 2351 electric locomotives of all kinds with an aggregate h. p. capacity of 4,259,148; of this number 1446 locomotives operated on alternating current and 905 on direct current, the aggregate h. p. being 2,780,692 and 1,478,456 respectively. Of these locomotives, 465 of a h. p. capacity of 862,596 were on the railroads of the United States, but this was exceeded by the Italian Railways with 504 locomotives of a capacity of 1,209,736 h. p. No other country has as many,—the next being France with 366 locomotives of 384,460 h. p. capacity, Germany with 304 locomotives of 518,841 h. p. and Switzerland with 214 locomotives of 384,152 h. p. No other country has as many as 150 electric locomotives in service.

A recent engineering achievement is the development of an electric locomotive which, in connection with a high-tension alternate-current contact wire, permits the choice on the locomotive of either single-phase or three-phase alternating current, or direct-current motors of any voltage desired. Thus a very long step has been taken toward a standard or at least uniform system of contact wire which enables those railroads using it to freely interchange traffic with locomotives of several different kinds.

The rapid development of the so-called "Superpower System" of interconnecting electric power-plants is working to the advantage of the railroads, as this plan makes available an abundant supply of reliable electric power at many different points and will enable a railroad to be electrified without the necessity for the very large investment for power-house and machinery otherwise required. The superpower system will also bring to the railroads an amount of power and a safeguard by means of interconnection

with other power houses that would not be possible for any one company to provide with any reasonable expenditure.

It is seen, the engineering and manufacturing requirements for electrification are very well provided and there need be no hesitancy in proceeding with large plans for electrification on this account.

What are the future requirements of our railroads, broadly considered?

During the past ten years little, if any, expansion of our railroad mileage has been made. The financial resources of the country were required for war purposes and after the war, for a rehabilitation of our financial structure. It is only recently that serious attention has been directed toward the necessity for developing our railroad systems.

Much progress has been made by the railroads during the past two years in improved efficiency and this has so well provided for current needs of business that the inevitable expansion and growth of our railroad facilities is to some extent masked by the better service rendered possible by the increase in efficiency. There is, however, a distinct limit to the possibilities of improvement along this line and we must look forward to a broader development of railroad facilities in the very near future.

All of us engaged in industrial work have very vivid recollections of the paralyzing results of the car shortages in 1912 and 1913 and during the many other similar periods in our industrial history. This situation is better today only because of the remarkable improvement in the operating efficiency of the railroads and the fact that the volume of traffic today is not up to the full requirements of industrial prosperity; but it is not only car shortage that causes serious deficiency in satisfactory railroad freight movement. It is because railroads become congested due to the inadequacy of their terminals and it is in the improvement of such terminal facilities that much relief in the movement of traffic can be obtained.

There is ample evidence of the value of the electric locomotive in switching service. In a recent article by Mr. Herbert Quick, published in "The Annals of the American Academy of Political and Social Science" for the month of March, he states—

"The New York, New Haven & Hartford Railroad recently put into service sixteen electric switchers, operating in the crowded terminals of New York City and vicinity and through the dense industrial belt of New England, which faces a most acute terminal crisis whenever business is good. These electric switchers on many occasions have run 24 hr. a day for 30 days without interruption. So efficient is their service that six electric switchers take the place of ten steam-switch engines."

"On the Philadelphia, Paoli and Chestnut Hill electrified division of the Pennsylvania Railroad the schedule is made with such regularity as to record 10,000 train miles to every detention. This is substantiated also by the record of the 33 electric locomotives that have handled passenger traffic in and out of the Pennsylvania Terminal at New York City for the past fifteen years. They have made 11,456 miles for every minute of detention, including electrical, mechanical and man facilities."

Electric railways have been in successful operation for upwards of twenty years, during which time the cost of production of electricity has steadily decreased and the reliability with which it can be handled and its availability to railroads has constantly been improved.

Here, therefore, is a means by which the capacity of the railroad can be increased with a minimum expenditure and at the same time its efficiency very materially improved. In addition, by saving the transport of much of the coal now used on locomotives, for the super-power stations will be either hydraulic or so located as to necessitate the minimum transport of fuel. And the actual capacity of the railroad as a transportation medium is increased for revenue freight of other kinds.

Again, with electric power, the trunk line railroads can concentrate much larger amounts of power in each train than is possible with steam locomotives on account of the limitation of the steam locomotive boilers. This concentration of power in main line traffic means larger trains and higher speed, or both, if necessity requires, and almost without limitation.

Great railroad arteries of traffic handling main-line commerce between our great cities are really wholesalers of transportation and, therefore, have a problem differing both in kind and quantity from the smaller lines engaged more generally with local traffic. Electrification becomes more and more important as the volume and concentration of traffic increases. It is, therefore, these heavily loaded main lines which can most advantageously study this problem.

Is it not, therefore, clear that the time has arrived to expand the use of this wonderful force of electricity in developing and improving our railroad service? In no other way can so great results be attained per dollar expended.

It may be said that any broad program of electrification would require a very large expenditure of money. So it would, but money so expended, of course with careful discrimination, would return splendid dividends to its far-sighted investors and at the same time give to our country a service without which all industry will languish and fail.

I will conclude as I began with the statement that "Adequate and efficient transportation is the prime necessity of modern civilization." The age of electricity is supplanting steam as a direct producer of power and railroads are no exception to this rule.

THE EXECUTIVE'S STANDPOINT

By C. H. Markham

President, Illinois Central Railroad

The announcement that the manufacturers of railway electrical equipment are now in a position to develop and construct any system of installation desired is of great interest to railway men.

The development of facilities for railway operation under electrical power has heretofore been along more

or less limited and individual lines. The results of the experiments that have been conducted and the installations that have been made under this handicap constitute a valuable contribution to the technique of electrification. But, now that the handicap has been removed and the field of joint study has been broadened, I believe even greater contributions will be forthcoming.

The railroads have two objects in making expenditures for improvements in their properties. One is to give them the capacity to handle their constantly increasing traffic; the other is to enable them to perform that service at a constantly decreasing cost per unit of service and per unit of investment. I believe, as I am sure you do, that there are great possibilities for electrification in both these directions, but I want to remind you particularly of the possibilities that exist in the direction of reducing the cost of service. It is in that direction that the future of electrification largely lies. When you can satisfy railway managements and enable them to satisfy the Interstate Commerce Commission and prospective investors that electrification will produce economies of operation sufficient to pay a liberal return on the investment necessary to make the installation, electrification will go forward rapidly.

Most of you are no doubt familiar with the fact that within the last two years the railroads have spent more than one billion dollars a year for property improvements. Their future needs have been estimated as high as one billion dollars a year for some time to come. If this rate of expenditure is maintained, even in the approximate, it means that in a comparatively few years the railroads will have doubled the amount of their property investment. If they are to realize a reasonable return upon this doubled investment without increasing their rates, the property improvements for which the money is spent will not only need to increase their capacity, but will also need to effect reductions in the cost of operation substantial enough to overcome their increasing taxes and produce a margin of profit.

Moreover, the railroads will not be satisfied to go along making these large expenditures without, at the same time, making it possible to effect reductions in their rates. Business will be accelerated and prosperity will be encouraged as the railroads are able to reduce the level of their rates and still maintain sufficient net earnings to protect their credit. If such rate reductions are made, they will have to come out of operating economies produced by more efficient facilities and improved operating methods. The manufacturers of railway facilities of all kinds, including electrical facilities, have an opportunity to contribute toward that end.

In the joint study about to be undertaken I want to remind you that each railway project constitutes a problem of itself. The conditions that *make* problems in railway operation, vary from one railway system to another and, on a single railway system, from one part of the country to another. Therefore, the solution of the operating problems of one railroad is not necessarily the solution of the corresponding problems of another; and the same is true of the various parts of a single railway system. Your study will need to be sufficiently diversified to meet the varied conditions of location, traffic, and so on.

There is another factor that will have a great bearing upon the future of electrification as applied to the railway industry. That is the factor of simplicity. The equipment and other facilities used in railway operation will need to be operated and maintained largely by the present operating and maintenance forces of the railroads. Simplification of electrical facilities will therefore have a great deal to do with the success of installations that are made and the adoption of electrification elsewhere. Of course, simplicity must not be gained at the expense of efficiency and economy.

Standardization is still another factor that will do much to make installations of electrical facilities successful, bearing in mind that they will have to be operated and maintained largely by present railway forces. The personnel of a railroad must necessarily have a large degree of flexibility. The man who is trained to operate or repair a facility in use at one point must possess the same qualifications with respect to other comparable facilities. Interchangeable parts are necessary to reduce stocks of materials on hand and to facilitate the making of both light and heavy repairs. All these things call for the greatest standardization of design that is compatible with efficiency and economy.

I understand that the goal to be sought in the field of research into which the electrical fraternity is about to enter is: "What is best shall be done." I commend to you the spirit of that slogan and offer you my heartiest good wishes for the success of your endeavors. The perfectly astounding accomplishments up to the present by the electrical engineers of the world should be a stimulus to you in the work you have undertaken.

THE RAILROAD COMPANY'S VIEW OF THE ELECTRIFICATION PROBLEM

By Robert J. Cary

General Council, New York Central Lines

A LAWYER who represents a railroad company develops a great deal of temerity in invading fields of discussion reserved for experts. I doubt that there is any other industry in the United States that has so many ramifications of distinct activities as the railroad, and in which the lawyer is called upon to participate. The result of that situation is that we become amateurs in all lines and experts in none. I, therefore, speak before this organization of highly specialized minds with a great deal of diffidence. And the only way in which I can hope, so to speak, to get away with it is to keep entirely away from your field of terminology and lead you as far as I can into the territories that I understand, with the hope of

making apposite the points that I would like to make with respect to this subject matter.

In the presence of the overwhelming opinion of the great experts tonight on electricity, no one for a moment would suggest that the ideal development of the transportation systems of the United States is not along the lines of the substitution of electrical power for steam power. What I would like to point out to you tonight though, is that the problem is not an ideal one. It is more or less a concrete one. I was told tonight before I came here that this was to be more or less of an experience meeting of opposing views of experts who had now reconciled their views and were tendering to the carriers of the United States, on a platter, a common attitude in anything that they desired with respect to the subject matter of electrification. I congratulate any specialty in the United States, any profession that can be of complete unanimity of opinion on any fundamental subject. Certainly, it is not true in my profession. We have nothing of interest if we agree upon anything, for discussion, controversy in pursuit of the truth is the very life of the profession to which I belong.

Now with those policies, I am going to say a few things which will suggest perhaps that the problem is not ideal and that leads up to this: However expert we, the railroad people, may be in transportation we are admittedly not experts in electrification. We recognize that the problem is not an exact science. I don't believe there is any exact science in this world today, even in mathematics, I am told now. But we are in the position where we manufacture and sell transportation and you manufacture and sell power and it is clearly our business to keep out, if we can, of your field. We are accused of invading your field. We have our own power stations in some respects. We believe that that has grown out of the fact, perhaps, that we were so far apart years ago when those stations were built, so far unwilling to meet positions of compromise that each side to this problem went his own way in a categorical manner without conceding anything to the position taken by the other side, however unscientific or uneconomical each may have thought the other. I believed, I still believe, that any man who deals in categories is always inexact. It is a very difficult proposition to assert any truth in a universal generalization, because no one of us has such profound knowledge of a subject that we can state the proposition in such a way that there will never be exceptions. Now, in applied science, whether it be the application of the science of railroading to moving persons and goods across country, or in your science of manufacturing and selling power to public utilities and transportation systems, the statement that I have made has conspicuous application.

We need to reconcile principles with recognized propositions of expediency, and nowhere is that more apparent that in this subject that we are discussing tonight, or indeed, in any phase of the transportation problem. Now the deterrents to progress in electrification of railroads, if not scientific, are at least real. In the first place, the great transportation companies of the United States have been notoriously living from hand to mouth. We are told today by the statute law of the United States that we are entitled to earn upon our plants 5¾ per cent. On the average we, the carriers of the country, have not approached this amount. Every problem that confronts a railroad must be viewed in the light of this situation of living from hand to mouth.

Now the railroad manager, when he is confronted with the proposition of electrification, discovers in the first place that he hasn't any money and it costs a great deal to get money and he has a tremendous initial cost. He can be shown the fields beyond which he is going to be lead into reduced periods of maintenance, in the ideals of efficiency and transportation. But it is very difficult for him to persuade his laymen directors that, as an abstract proposition, is true and he has to find a great deal of money for his electrification. He also doubts, and he may be wrong in this respect, that when the peak-loads of business fall off and there are months of stagnation that if he electrifies his system he can curtail the equipment in his plant and cut down his overhead as easily as he can store all his engines, even if his engines do wear out. It is easier to put his engines on the side-track than to shut down his whole electric plant, although again I have no doubt the experts can show that I am wrong in theory on this proposition.

Another thing confronts him and that is this: The easiest line or avenue of movement is the one that he often pursues. I am told that in the last twenty years there has been a complete revolution in the art of the development of the steam locomotive. That its efficiency has been tremendously improved, its power has developed and its standardization confronts the railroad manager so that he has a pretty easy problem and the curve of ascending cost is gradual, as compared, I am told, with that of the electrical locomotive. On the other hand, until tonight, when there has arisen complete unification in a desire and wish in attempting to sell the railroads of the United States exactly what they want, when he goes to the people of the United States who engage in selling or first manufacturing and then selling power, he finds that the expert doctors disagree.

Now, as I say, I am going to keep away from your terminology. I have heard tonight, however, that some think we should use alternating current and some direct current. Hitherto, we had been confronted with the specialists on this subject. It isn't so important from the standard of the layman and the railroad people of the United States which of those principles we employ. It is highly important though that the doctors agree among themselves and tell us as experts what we ought to have and tell us in accordance with our concrete

problems what is their consensus of opinion as to the best thing for each problem. The railroads of the United States, when they find their doctors diagnosing their cases on that kind of a basis, will find that the proposition, or will receive the sale of the proposition, with much less scepticism from the standpoint of ideals of the problem than they do now.

We need, as Mr. Markham said in the paper that has just been read, some means of obtaining cheap power, and as I say, it can't be handed to us all along the ideal lines. The problem must be studied concretely and it must be made immediate, because we, the railroads of the United States are in one sense a good deal like the telephone companies; we will never catch up with the demands in our capital expenditures. A billion dollars a year is a large sum to expend but it is called for and if it falls off in any one year owing to the want of appreciation of the public authorities in giving the railroads of the United States the opportunity to protect their credit, not only to protect their credit in borrowing money, but to make those who own the railroads be willing to put more money into them, that is, to buy stock and to become owners, we shall never catch up with the population of the United States in the demands for the increase of our plants.

Now, that is the great situation which confronts the transportation companies of the United States. We, therefore, must find a need for cheap power and we must also find the means of universal standardization for the purpose of enabling us to buy the instrumentalities to obtain that cheap power.

Now gentlemen, that is one side of the proposition. That might be called in part the engineer's side. Now there is the commercial side—I am going to talk with a little more confidence on a subject that I know a little bit more about; and I will venture the assertion that there is no industry, and I call a railroad an industry, which approaches the situation of determining its economic condition with more difficulties confronting it than do the great transportation systems of the United States. Cost accounting, in its larger and non-technical sense, is in its infancy in the railroad world. You may not believe that, but let me suggest to you a few of the factors involved.

In the first place, we have no accurate knowledge, of the value of our plants. We have no accepted conventions for the purpose of measuring the value of a railroad. We can get the experts to figure and the courts to render opinion, but today there is totally wanting a series of conventions by which the value of any one of the big railroad plants of the United States can be determined. The Government is spending millions and the railroads of the country are spending many more for the purpose of determining the value of the railroads of the United States; and long before the figures are assembled they are obsolete. Long before a point is reached where an inference can be drawn we are in such a position that the whole situation is archaic with respect to the subject matter for which our figures are to be used. The Interstate Commerce Commission is endeavoring to compute on the basis now of 1914. The courts and the commissions of the United States can render opinions on the questions of the factors that are needed in valuation and comparatively few of them agree.

We are still without a means of putting our finger on the dollars and cents value of the plants upon which we are entitled to earn 5¾ per cent.

In the second place, on the subject of what it costs to transport property, persons and commodities, we are again without conventions. We have our views as to how much it will cost to carry passengers from New York to Chicago, but we are inaccurate. We do not know beyond perhaps one-half of the factors how to scientifically allocate the overhead charges or the indirect charges that enter into the cost of transportation. No one has attempted to lay down conventions for the purpose of covering particular commodities, and, therefore, we are again in a field of speculation.

Finally, (and this comes home particularly to this subject, because electrification is now being addressed largely to terminals), it is a very difficult proposition to determine the distinction between the return which comes from an approved terminal and that which comes from it in connection with the railroad as a whole. There is no scientific means of segregating our properties into parts for the purpose of determining how much is earned on this piece and how much is earned on that piece. The railroad is a composite unit made up of perhaps thousands of units, differing from most industries of a complicated character in that those units are spread over thousands of miles of territory and each has a reflex action upon all the other units. A railroad may become too heavy in terminal investments from the standpoint of the cost of capital charges in handling those terminal investments. We may, according to the ideal problem, electrify those terminals, and upon the theory of the segments passed upon by the experts, reduce the cost of operations as to that particular segment. Even if our rates are not reduced by the opportunist public-utility commission that sees the reduction in cost, we still may be confronted where the unit as a whole has not been benefited by the improvement of that particular segment.

The terminal problem is the greatest problem of the railroads of today. It is the tenacle by means of which the trunk reaches the public. It is the sensitive part of the railroad in coming in contact with the public. It is a very difficult thing to say that there is a direct or an immediate return to the unit as a whole because of the development of this terminal by itself. The problem of New York in electrification is different from the problem of Chicago. The problem of the Grand Central Passenger Terminal in electrification is different from the West Side problem. The problem in Cincinnati, in Cleveland, in all the cities with which the

lines I know of have to do is concrete, relative and not ideal and each one must be considered on the basis of its own situation.

The last thing before you is the proposition of applying these principles that I have heard here tonight. In going your way, you must begin with those. They are unanswerable; they undoubtedly represent the truth; there is no question about it. I couldn't or wouldn't intend to refute them for a moment, and in the railroad world it is essential that we should have imagination. I believe, contrary to public opinion, that the railroad business has not approached the stereotyped. The opportunity for imaginative effort in the cause of its complications is greater perhaps than in any other industry in the United States. Therefore, my suggestion to you and indeed to the railroads tonight, is that this problem should be approached with a concerted appreciation of the situation; and that the principles which are ideal should be considered with those that are commercial; and that, as is always, the situation in every step of progress in this world, either material or ideal progress, must be a constant compromising of principles with the occasions of expedience so that the truth may be approximated and by that means we may take the next step in evolution to approaching the ideal.

ILLUMINATION ITEMS

By the Lighting and Illumination Committee

HIGH INTENSITY AND EYE-FATIGUE

By P. W Cobb and F. K. Moss

Lighting Research Laboratory, National Lamp Works, Nela Park, Cleveland, Ohio

The problem of proper illumination for the modern industrial plant is receiving increasing attention from plant managers. Numerous practical tests[1] have been made and the results of such investigations have stimulated further activity in this field, and in consequence, the average intensity of illumination in use has steadily increased. The improvement in production and the betterment of working conditions in general, has been brought about by increasing the intensity of both local and general lighting, and by carefully designing the distribution of the light.

The question of possible harmful effects of "high" intensity upon the eyes of the workers has been raised and experimental work in the laboratory done to note the effect, if any, produced by the higher intensities. It is well known that lighting installations which produce "glare" are objectionable, but in such the objection has been to the glare and not to the intensity of illumination.

Both experimental tests in the laboratory and in actual practise have established the fact that in work where the sharpness of vision is important, that increased production and accuracy[2] have been obtained with an increase in the intensity of illumination. It is interesting to know whether such an increase in production and accuracy with which the work is accomplished takes place at the expense of greater eye-fatigue. If the high intensity produces a greater eye-fatigue, then when the amount of work performed using high and low intensities is made the same, the operation done under the higher level of illumination should be the more fatiguing.

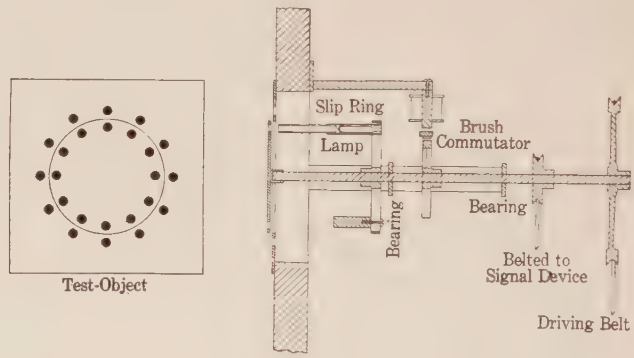
The results and conclusions given in this discussion are based upon the above hypothesis. It is necessary, because of the limitations of the laboratory, to limit the problem to the comparatively short-time effects of visual work and to assume that the results obtained from an exceedingly exacting piece of work done in a short time would be comparable to work of usual difficulty maintained for much longer intervals.

In performing the test, the experimental work was divided into two parts:

1. Producing a measurable amount of eye-fatigue by controlled methods.

2. Measurement of the fatigue thus produced.

The eye-fatigue was produced as follows: A test-



Apparatus for Measuring Eye Fatigue

object consisting of a white disk with twelve equally-spaced holes near the rim was arranged so that it could be rotated at any desired speed. Surrounding this disk were twelve holes of the same diameter drilled in a white and stationary background. The subject was instructed to follow with his eye a given spot on the rotating disk and at intervals when this spot was in a radial line with a designated stationary spot, a key was to be pressed. The size and contrast of the test-object and the intensities of illumination used were of such an order that the test object was greatly above the limit of visibility. If the eyes of the subject succeeded in following the master spot (all spots were of the same appearance) and if the key was pressed at the proper time, then circuits were completed which operated two counting devices. One counter operated each time the key was pressed; the other operated only when the circuit was completed at the proper time. Thus one counter determined the number of trials and the other recorded the times the subject was successful in pressing the key at the right time. The manual skill required to synchronize the operation of the key

and the time when the two spots were in line was of secondary importance. At intervals of about thirteen seconds an audible signal was given and the subject pressed the key the next time the two spots were in line. Whenever the key was operated the master spot was illuminated thus enabling the subjects to check whether the right spot was being followed, and if not, to correct the error. This process was continued for thirty minutes without interruption, and at all times the subject was required to give the most concentrated attention to the problem, and no time was allowed for relaxation. The test often left the eyes of the subject in a reddened and watery condition and with no doubt in the mind of the owner that fatigue was present.

Fatigue, in the physiological sense, may be regarded as a temporary impairment to function following continued activity. The balance of the extrinsic muscles of the eye seemed to be a function of just such a highly coordinated and delicate mechanism as could be expected to undergo such impairment readily as the subject attempted to follow the rotating spot. Accordingly, the muscle balance of the subject was measured before and after the test and the difference between the readings ascribed to fatigue.

SUMMARY OF DATA

Brightness 100 ml.

Muscle Balance					
Before Test		After Test		Arith. Dif.	Score
Δ	*E*	Δ	*E*		
s 2.4	.115	*s* 2.7	.159	.3	100
x 0.5	.038	*s* 0.1	.052	.6	101
s 0.7	.060	*s* 0.9	.155	.2	81
s 1.0	.041	*s* 0.7	.048	.3	106
s 1.2	.072	*s* 0.3	.095	.9	110
s 4.1	.138	*s* 2.9	.079	1.2	108
s 8.2	.167	*s* 6.6	.216	1.2	111
x 0.6	.038	*s* 0.3	.069	.9	79
x 1.9	.079	*x* 1.5	.069	.4	114
Average				0.67	101
Probable Error				0.105	
Brightness 5 ml.					
s 3.0	.193	*s* 3.6	.272	.6	105
x 0.7	.053	*s* 0.2	.052	.9	104
s 0.4	.059	*s* 1.2	.088	.8	77
s 1.5	.014	*s* 1.1	.055	.4	112
s 1.2	.072	*x* 0.1	.055	1.2	116
s 3.1	.126	*s* 3.1	.079	0.0	111
s 7.5	.173	*s* 6.3	.136	1.2	110
x 0.6	.069	*s* 0.6	.072	1.2	72
x 1.7	.045	*x* 1.4	.072	0.3	113
				0.73	102
				0.108	

(*x*) Exophoria
(*s*) Exophoria
(Δ) Centrad; Equivalent to 1/100 of a radian
(*E*) Individual probable error.

In the table is presented a summary of the data from nine subjects taken on five occasions for each intensity of illumination. The quantities listed under the heading "score" are the number of correct operations performed out of 120 trials. The averages are nearly identical and establish the fact that the work was done equally well under 5 ml. as under 100 ml. There was obtained, however, a significant shift in the balance of the eye muscles produced by the thirty minutes of continuous ocular work. This change amounts to some six times its probable error and indicates that the test altered the muscle balance to a measurable degree. It will be noted that there was no significant difference of the muscles balance readings for high and low intensity.

Although this particular task could be performed by the eyes as well with the lower intensity, the higher illumination was in no way harmful or tiring to the eyes of the worker, and hence the factor of eye-fatigue does not appear to detract in any way from the advantages of "high-intensity" illumination.

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THE LIGHTNING DEMONSTRATION AS AN EDUCATOR

Visual education, or in other words, education through visual means plays a very important role in our daily life. We all know that. It is only natural, then, that modern educational methods are turning more and more toward the use of those visual aids which assist us in grasping a thought with the least expenditure of time and energy—for in this respect a look is indeed worth a thousand words. Exhibits illustrating the various stages in the refining of asbestos, or sugar, or in illustrating the life and work of the honey -bee or whatnot are frequently used in grammar schools as a "sugar coated" means of educating the child. Likewise actual experimentation and demonstration are used in our high schools and colleges to make various facts more clearly understandable to the student.

Not alone in the class room, but in other fields as well, visual demonstrations can be used very advantageously. This is especially the case wherever the working principles of good lighting practise are to be explained to the average fellow—the man at the desk or machine. Lighting conditions, you know, unlike the automobile engine, give no warning knock, cough or backfire, or other emphatic indication that there is anything wrong with them. Indeed, much of the information pertaining to the proper use of light is somewhat intangible, and unless the speaker or writer is particularly gifted it becomes even more so. This same information, however, becomes alive with interest when it is actually demonstrated. It is a simple matter, then, to interest

the layman in pertinent facts about lighting and to direct attention to the features in the applications of artificial lighting which are for his well being. Simple lighting demonstrations, thus, enable him to learn how to judge the qualities of good lighting for himself. This knowledge is beneficial not alone to himself, but to others as well for he is certain to offer helpful suggestions for improving such lighting conditions as tend to create eye-strain and eye-fatigue.

Let us consider for the moment, some of the applications of the demonstration, and the reasons for its existence. Take, for example, the broad field of street lighting. At the present time a great many of our cities, both large and small, are beginning to realize that good street lighting is a very valuable asset. And indeed it is, for it allows the motor car owner to drive with greater ease and surety, which in turn greatly reduces the possibility of accidents. Good street lighting also decreases crime and helps to maintain the municipal pride and progress of any community.

Before good street lighting can become a reality, however, financial arrangements must be made, engineering plans must be drawn up and a suitable type of equipment must be selected and installed. In most cases the city council, or a similar representative group of persons, is active in the accomplishment of these things. In spite of the fact that such a group of city fathers generally holds the complete confidence and trust of the people it represents, and should therefore perform its duties in such a way as to obtain the greatest benefit, still these groups of city fathers will frequently attempt to select a suitable street lighting system by a mere blueprint. Such a print cannot convey any mental picture of the night time appearance of any type of street lighting and hence is a makeshift method of selection. Contrast this with the more logical method of selecting a system of street lighting from an actual night-time demonstration, such as the Cleveland Street Lighting demonstration mentioned in the Nov. 1923 JOURNAL. By such a means, a city council can readily compare one system with another as regards illumination on the pavement, spacing distances, sizes of lamps and similar factors. Consequently there is little danger of the city council installing a system which will be entirely inadequate and unsatisfactory to the residents. When considered in this light, is not the lighting demonstration a veritable blessing to ambitious communities?

It is a surprising fact that factory managers and plant executives have not all become aware of the great losses which they sustain each year, because of poor lighting alone. Actual tests have shown that inadequate lighting seriously retards production and the resulting losses are estimated at over four billion dollars annually. Will it not, then, be advantageous for the factory manager or plant executive to witness a factory lighting demonstration so that he may understand the meaning of that purely relative term "Good illumination"? For, by switching on one system after another, glare, specular reflections, shadows, efficiency and other lighting factors cease to be vague, abstract names—they become real and vital. There arises, then, a definite realization that men cannot do their best work under haphazard lighting conditions, in which, perhaps, dazzling lamp filaments at close range, play havoc with the eyes of the workman, or in which univiting gloom yields an atmosphere of depression and sinisterness.

Other fields as well benefit from the use of the lighting demonstration. The store owner learns how to employ light in his show windows or show cases in the most attractive and useful manner. The automobile owner learns how to adjust his headlights and the reasons for so doing, thereby reducing the danger to himself and to others from glaring headlights. The home lover learns how light may be used to beautify his home and make it a true home in every sense of the word. And so it goes, the lighting demonstration offers many opportunities in each and every one of the applications of artificial light.

Indeed, the possibilities in the use of lighting demonstrations are so great that illuminating engineers and others interested in the lighting industry exerted their energies towards making the lighting demonstration an even more important factor in the industry. Various organizations in the lighting field have already installed permanent demonstrations of this nature and the future will, doubtless, witness a considerable increase in this field.

DETECTION OF FLAWS BY MAGNETIC ANALYSIS

The Bureau of Standards has been engaged for some time in a study of magnetic method for the detection of flaws and defects in steel, with particular reference to wire hoisting ropes. The economic value of such a nondestructive method would be very great. Many investigations along this line have been made at the Bureau and elsewhere, but the uncertainty in the interpretation of results has hitherto been an obstacle in the way of practical application.

Experiments have also been made at the Bureau to discover the cause of this uncertainty, and a method of eliminating it. It has been found that the greatest source of difficulty is the effect of variations in internal stress within the specimen. Such variations give rise to large differences in magnetic permeability, which produce effects similar to and often greater in magnitude than those caused by the flaws in the material. The results of recent experiments show that by the use of higher values of magnetizing force than have heretofore been employed, the effect of internal stress is greatly reduced without a corresponding reduction in the effect of flaws. It thus appears that one of the greatest difficulties in the way of the practical application of this method has now been overcome. The experiments are being continued to determine whether or not sufficiently accurate interpretation of the results of magnetic exploration can be made to permit of its use as a practical inspection method.

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Technical and Recreational Events of Annual Convention

A program combining selected technical papers, delightful recreation and other features has been arranged for the Annual Convention which will be held at the United States Hotel, Saratoga Springs, N. Y., June 22-26. The technical meetings will cover such subjects as distribution, circuit breakers, electrophysics, magnetism, transmission, telegraphy and hydro-electric development. There will also be presented reviews of the latest progress in many branches of electrical engineering, including machinery, generation, power stations, protective devices, transmission, lighting, communication, industrial applications, electrochemistry and electrometallurgy, electrical measurements, marine work, research and standards.

Ideal Place for Recreation

The program has been so arranged that each afternoon can be devoted to sports, automobile rides to points of interest in the Adirondacks, and other recreations. Lovers of golf will have an opportunity to play on one of the best eighteen-hole links in the country at the MacGregor Country Club on the outskirts of the city. A beautiful club house with broad veranda offers delightful views of the Green and the White Mountains, as well as the Adirondacks. Accommodations can also be made to use the nine-hole course at the Saratoga Country Club.

Many visitors will take their own cars to the convention. For those who enjoy horseback riding, saddle horses can be rented. There are any number of interesting spots to be visited. The city has miles of beautiful drives and in the state reservation will be found many drives surrounded by the fragrance of pines. But ten miles distant is the famous Saratoga battleground, where the battle monument and other interesting and historic tablets are to be found.

Fishing, bathing and boating may be enjoyed at Saratoga Lake, four miles from the city. Here are to be found nationally famous shore dinners.

Lake George is 25 miles from Saratoga and easily accessible by auto, trolley or steam railroad. Two large boats are operated on this picturesque body of water.

Saratoga Springs is a beautiful city. The air is a tonic, full of freshness of the pine forests. It is ideal for rest, relaxation and social pleasure. In the parks may be found some of the most beautiful examples of landscape gardening. The magnificent gardens and park in "Yaddo," the late Spencer Trask's estate, is a most beautiful point of interest.

Many Ladies Will Attend

The opportunities for recreation make this convention particularly attractive to lady guests and a large number of them will attend. Many plans have been made to insure their enjoyment.

There will be a reception and dance on Tuesday evening and dancing will also be enjoyed on other evenings.

Addresses on Hydroelectric Developments

The technical papers are limited in number to allow plenty of time for recreation but their quality is excellent. In addition to the regular technical sessions there will be an evening meeting on Wednesday with two addresses on hydroelectric development. *Power Possibilities at Muscle Shoals* will be the subject of the first address which will be presented by Samuel S. Wyer, consulting engineer. Following this William S. Lee, Vice-President and Chief Engineer of the Southern Power Company, will describe *The 540,000-h. p. Hydroelectric Development on the Saguenay River at Isle Maligne, Quebec.*

Engineering Education at an Evening Meeting

On Thursday evening it is planned to have an address on engineering education by Dr. W. E. Wickenden, Director of Investigations of the Society for the Promotion of Engineering Education. Dr. Wickenden has been in Europe for several months studying the educational systems of several countries there.

Meeting of Section Delegates

The delegates from Institute Sections will meet all day Monday of the convention week under the auspices of the Sections Committee. All members of the Institute are invited to this meeting.

Inspection Trips

On Wednesday afternoon a trip will be made to Schenectady to visit the works of the General Electric Company.

Visits will be made on other afternoons to plants of the Adirondack Power and Light Company. Three plants are of special interest, namely, the Amsterdam steam generating station, the Sherman Island hydroelectric plant and the Rotterdam high-tension substation.

The Ford Green Island Plant which includes a very low-head hydroelectric plant will also be visited.

Sightseeing Trips

Sightseeing trips which will be of special interest may be made to the Saratoga and Schuylerville battle fields, to Saratoga Lake and to Lake George.

Special Railroad Rates

Reduced railroad fares from most points have been granted on the certificate plan. This plan requires that a certificate be obtained from the selling agent when the one-way ticket to the

convention is purchased. Presentation of this certificate at convention headquarters will entitle the purchaser to one-half rate for the return trip over the same route *provided at least two hundred and fifty certificates are presented at the convention.*

Every person should get a certificate whether he will use it or not as it is needed to make up the 250 certificates which will allow others to obtain the reduced return fare.

Hotel Reservations

Those desiring hotel reservations during the convention should communicate directly with the hotel management. In the following list are shown the rates of the convention headquarters, the United States Hotel, and of other hotels. Accommodations at private houses may be obtained through the Chamber of Commerce of Saratoga Springs.

HOTEL RATES—PER DAY

	Single Room		Double Room	
	without bath	with bath	without bath	with bath
United States (with meals)	$6.00	$7.00	$12.00	$14.00
Worden (with meals)	6.00	7.00	12.00	14.00
American (with meals)	6.00	7.00	12.00	14.00
Saratoga Inn (without meals)	2.50	4.00	4.00	6.00
Western Inn (without meals)	2.00		3.00	
Summer Rest	5.50			
Cottage (with meals)	6.00			
Wellington Cottage (with meals)	5.00			
Willets Cottage (with meals)	4.50	5.00		
Hotel Russel (with meals)	4.50			

Register in Advance

Registration should be made in advance, if possible, to facilitate the work of the committee in charge. Send notice of registration to the American Institute of Electrical Engineers, 33 West 39th Street, New York City.

The Convention Committee

An energetic committee has been handling the local arrangements for the convention. This committee consists of: J. R. Craighead, Chairman; H. H. Dewey, N. F. Hanley, L. W. W. Morrow, F. W. Peters, L. T. Robinson, Harold B. Smith, John B. Taylor and C. S. Van Dyke.

The chairmen of the subcommittees appointed to date are as follows: F. W. Peters, Finance; J. B. Taylor, Entertainment and Social Events; H. H. Dewey, Games and Athletics; C. S. Van Dyke, Excursions; L. T. Robinson, Music; C. E. Mochrie, Transportation; H. W. Samson, Publicity and W. A. Sredenschek, Hotel Accommodations.

PROGRAM OF ANNUAL CONVENTION, SARATOGA SPRINGS JUNE 22-26,

Monday, June 22, 9:30 a. m.

Section Delegates Conference

Monday, 2:00 p. m.

Section Delegates Conference

Tuesday, 9:30; a. m.

President's Address

Technical Session

Present State of Transmission and Distribution Developments, by Committee on Power Transmission and Distribution, P. H. Thomas, Chairman.

Live Problems in Connection with Protection of Electrical Systems, by Committee on Protective Devices, H. R. Woodrow, Chairman.

Latest Design and Practise in Power Plants, by Committee on Power Generation, Vern E. Alden, Chairman.

Developments in Electrical Machine Design, by Committee on Electrical Machinery, H. M. Hobart, Chairman.

Precision Watthour Meters and High-Frequency Measurement, by Committee on Instruments and Measurements, A. E. Knowlton, Chairman.

The Activities in Research, by Committee on Research, John B. Whitehead, Chairman.

Tuesday Afternoon

Recreation

Tuesday Evening

Reception and Dance

Wednesday, 9:30 a. m.

Technical Session

Developments in Applying Electricity to Industrial Uses, by Committee on General Power Applications, A. E. Waller, Chairman.

Electricity's Progress in the Iron and Steel Industry, by Committee on Applications to Iron and Steel Production, F. B. Crosby, Chairman.

Advances in Use of Electricity in Mines, by Committee on Applications to Mining Work, F. L. Stone, Chairman.

Rules and Personnel Problems of the Marine Field, by Committee on Applications to Marine Work, L. C. Brooks, Chairman.

Progress in Diverse Lines of Electrochemistry and Electrometallurgy, by Committee on Electrochemistry and Electrometallurgy, George W. Vinal, Chairman.

A Year's Progress in Lighting, by Committee on Production and Application of Light, G. H. Stickney, Chairman.

Recent Advances in the Communication Art, by Committee on Communication, O. B. Blackwell, Chairman.

Revised Standards and the Organization of Standards Activities, by Standards Committee, H. S. Osborne, Chairman.

Wednesday Afternoon

Trip to General Electric Company

Wednesday, 8:30 p. m.

Addresses on hydroelectric developments

Power Possibilities at Muscle Shoals, Samuel S. Wyer, Consulting Engineer

The 540,000-H. P. Hydroelectric Development at Isle Maligne, Quebec, William S. Lee, Vice-President and Chief Engineer, Southern Power Company

Thursday, 9:30 a. m.

Technical Session A

Engineering and Economic Elements of Two-Phase, Five-Wire Distribution, by P. H. Chase, Philadelphia Electric Co.

An analysis of the merits of the two-phase, five-wire secondary distribution system as compared with other systems. Among the customer requirements considered are continuity of service, safety, standard voltages, voltage regulation and balance, and utilization equipment and wiring. Among the distribution-system requirements are simplicity, standardization, load and voltage balance, adaptability to physical conditions and to growth, investment, losses, costs, and the combination of lighting and power secondaries.

The Oil-Circuit-Breaker Situation from an Operator's Viewpoint, by E. C. Stone, Duquesne Light Co.

This paper is an assembly of the present knowledge on (1) factors affecting interrupting capacity, (2) features of design considered essential, (3) factors affecting interrupting duty, (4) relations between ratings and cost, (5) present status of interrupting ratings and (6) applications and maintenance.

The Quadrant Electrometer, by W. B. Kouwenhoven, Johns Hopkins University.

This paper discusses the theory of the quadrant electrometer in respect to power measurements and reduces the general equation to a simple form. It shows how the constants may be determined with continuous current and that these constants apply also in a-c. power measurements.

A New Method and Means for Measuring Dielectric Absorption, by R. E. Marbury, Westinghouse Electric & Mfg. Co.

An instrument called a "dielectric lag meter" for measuring dielectric absorption has been developed. This paper tells of this instrument and its use in making measurements, particularly in three types of tests, namely: (1) residual voltage against time, (2) residual voltage against applied voltage and (3) discharge curves with condenser and resistance.

TECHNICAL SESSION B

Separate Leakage Reactance of Transformer Windings, by O. G. C. Dahl, Massachusetts Institute of Technology

This paper discusses an experimental method of determining as a separate reactance, the leakage reactance of transformer windings. The results obtained are consistent and accurate enough for engineering purposes.

Transformer Harmonics and Their Distribution, by O. G. C. Dahl, Massachusetts Institute of Technology

This paper discusses the distribution of harmonics in single-phase transformers. Formulas for distribution of harmonic currents between primary and secondary circuits are given. Laboratory and field test results check well with calculated values.

A New Two-Phase to Six-Phase Transformer Connection, by A. Boyajian, General Electric Co.

A new transformer connection for which is claimed 100 per cent apparatus efficiency for transformation from two-phase to six-phase is described in this paper. Its merits are compared with those of the Scott and the Woodbridge connections.

Resolution of Transformer Reactances into Primary and Secondary Reactances, by A. Boyajian, General Electric Co.

In this paper the stand is taken that the resolution of the leakage reactance of two windings into two separate reactances, one for each winding, is indeterminate unless referred to a third winding and that it varies according to the object in view. Formulas are given for some possible resolutions and experimental methods are described.

Losses in Iron Under the Action of Superposed A-C. and D-C. Excitations, by O. E. Charlton, Alabama Power Co. and J. E. Jackson, General Electric Co.

This study is particularly related to d-c. excited reactors and the results indicate that the iron losses are not excessive. In fact with high a-c. saturation they may decrease. The copper losses resulting from double-frequency circulating current may be considerable if the conductor is not sufficiently large.

THURSDAY AFTERNOON

Recreation

THURSDAY, 8:30 P. M.

Educational Meeting

FRIDAY, 9:30 A. M.

Technical Session

Study of Time Lag of the Needle Gap, by K. B. McEachron and E. J. Wade, both of General Electric Co.

Transients lasting only one-millionth of a second may be photographed by the adaptation of the Dufour oscillograph which is described in this paper. In this adaptation the photographic film is placed inside the exhausted tube. The paper gives an account of studies made with the instrument on the time lag of needle gaps.

Oscillograph Solution of Electro-Mechanical Systems, by C. A. Nickle, General Electric Co.

This paper describes a simple method for the easy solution of complicated dynamic problems such as those of electrical power systems or of mechanical systems. The method is of particular interest at the present time in connection with problems of transmission systems. The problem is set up on an "equivalent electrical circuit" and the solution is made by means of an oscillograph. The application of the method to several cases is illustrated.

The Klydonograph and Its Application to Surge Investigations, by J. H. Cox and J. W. Legg, both of Westinghouse Electric & Mfg. Co.

Four field investigations of surges on transmission lines made by the use of the klydonograph are discussed in this paper. There is also information on the latest developments in this instrument which utilizes Lichtenberg figures on a photograph emulsion for obtaining records of surges.

Overvoltages on Transmission Systems Due to Dropping of Load, by E. J. Burnham, General Electric Co.

This paper shows the manner in which voltage rises when load suddenly goes off a waterwheel-driven generator or a hydroelectric station. Tests and calculations prove that the voltage rises more rapidly and to a greater extent than has generally been realized.

The Loaded Submarine Telegraph Cable, by O. E. Buckley, Bell Telephone Laboratories, Inc.

A speed of over 1900 letters per minute or four times the traffic capacity of an ordinary submarine telegraph cable has been obtained on the new permalloy-loaded cable from New York to the Azores. This paper treats of the design and tests of the new type of cable particularly with reference to long-distance submarine application.

FRIDAY AFTERNOON

Recreation

Award of Institute Prizes

The Committee on Award of Institute Prizes, composed of L. W. W. Morrow, Chairman of the Meetings and Papers Committee, Percy H. Thomas, Chairman of the Power Transmission and Distribution Committee, and Donald McNicol, Chairman of the Publication Committee, reported to the Board of Directors at a meeting on May 15th, that it had made the following awards:

The *Transmission* Prize for 1924 to R. D. Evans and R. C. Bergvall, authors of a paper entitled "Experimental Analysis of Stability and Power Limitations," which was published in the April 1924 issue of the JOURNAL.

Honorable Mention to the following papers:

"Lightning and Other Transients on Transmission Lines," by F. W. Peek, Jr. (JOURNAL, August 1924).

"Corona Losses Between Wires at Extra High Voltage"—II, by C. Francis Harding (JOURNAL, October 1924).

The *First Paper* prize for 1924 to Murray F. Gardner, author of a paper entitled "Corona Investigation on an Artificial Line."

This year a large number of papers was submitted in competition for this prize and the Committee gave Honorable Mention to the following papers:

"The Prediction of Insulation Failures in Transmission Lines," by H. C. Hamilton and R. W. Chadbourne.

"Power Supply for Central Station Auxiliaries," by J. W. Dodge.

"Fault Finding in Power Transmission Lines," by S. Aronoff.

The Board of Directors accepted these reports and directed that the prizes be presented at the Annual Convention of the Institute, Saratoga Springs, June 22nd to 26th, in accordance with the regulations that have been adopted covering the award and presentation of these prizes.

Pacific Coast Convention

Progress is being made in the arrangements for the Pacific Coast Convention which will be held in Seattle during the week of September 15. The technical program will cover a number of topics. The problems of distribution, which are now of especial importance to the Pacific Coast, will be discussed in papers from several parts of the country. Transmission, of course, and hydroelectric development will also be featured.

The local committee in charge of the convention is as follows: Messrs. G. E. Quinan, Chairman, C. N. Beebe, Hiram W. Clark, Harry P. Cramer, E. J. DesCamp, W. C. DuVall, F. R. George, John Harisberger, C. A. Heinze, Joseph Hellenthal, Charles A. Lund, C. E. Magnusson, James S. McNair, C. E. Mong, L. W. W. Morrow and C. R. Wallis.

Future Section Meetings

Erie

Electricity in Mining. June 16.

St. Louis

Election of officers and Smoker. June 24.

Vancouver

Dinner and Annual Meeting for election of officers. June 5.

Annual Meeting of the A. I. E. E.

The Annual Meeting of the American Institute of Electrical Engineers was held in the Auditorium in the Engineering Societies Building, New York City, May 15, at 8:15 o'clock.

President Osgood, presiding, called the meeting to order and announced the first item of business: Presentation of the report of the Board of Directors. As printed copies of the report were distributed at the meeting, President Osgood merely called attention to some of the important items, mentioning particularly the excellent work during the past year which had been done by the Standards Committee, the Meetings and Papers Committee and the Publication Committee.

The next item of business on the program was the report of the Tellers on the vote on Constitutional Amendments. This report showed that all proposed amendments had been carried by a very large majority of the membership. Following this, the Tellers' Report on the election of officers was read by Secretary Hutchinson. Both of these Tellers' Reports are printed elsewhere in this issue of the JOURNAL.

President Osgood then declared the election of the following officers, whose terms will begin August 1, 1925:

PRESIDENT:	M. I. Pupin, New York, N. Y.
VICE-PRESIDENTS:	
District No. 2	Arthur G. Pierce, Cleveland, O.
District No. 4	W. E. Mitchell, Birmingham, Ala.
District No. 6	Herbert S. Sands, Denver, Colo.
District No. 8	P. M. Downing, San Francisco, Calif.
District No. 10	W. P. Dobson, Toronto, Ont.
MANAGERS:	M. M. Fowler, Chicago, Ill.
	E. C. Stone, Pittsburgh, Pa.
	H. A. Kidder, New York, N. Y.
TREASURER:	George A. Hamilton, Elizabeth, N. J.

These officers, together with the following hold-over officers, will constitute the Board of Directors for the next administrative year, beginning August 1, 1925; Farley Osgood, Newark, N. J.; Harris J. Ryan, Stanford University, Calif.; Edward Bennett, Madison, Wis.; John Harisberger, Seattle, Wash.; Harold B. Smith, Worcester, Mass.; L. F. Morehouse, New York; H. W. Eales, St. Louis, Mo.; H. M. Hobart, Schenectady, N. Y.; Ernest Lunn, Chicago, Ill.; G. L. Knight, Brooklyn, N. Y.; William M. McConahey, Sharon, Pa.; W. K. Vanderpoel, Newark, N. J.; H. P. Charlesworth, New York; John B. Whitehead, Baltimore, Md.; J. M. Bryant, Austin, Tex.; E. B. Merriam, Schenectady, N. Y.

President Osgood next introduced President-elect, Dr. M. I. Pupin, and congratulated the Institute on having elected for its next president, a man who was known all over the world for his wonderful achievements. Dr. Pupin responded in a few words, assuring the Institute that he appreciated the honor conferred upon him by electing him to be its presiding servant for the next year. He stated that he recognized in his election the endorsement of an old idea of his, that he had long cherished: "Abstract science, engineering and industry are an inseparable unit in our National life. This is the unit which is destined to carry the torch and illuminate the road which leads to the highest goal of this nation and that goal is the creation of an ideal American Democracy."

This concluded the business meeting and President Osgood announced the next subject of the evening, "Steam Railroad Electrification from the Executive's Standpoint," stating that it just happened to be an opportune moment for electrical engineers to open the door into a new era of railroad electrification work. He spoke of the divergence of opinion which had existed for many years in regard to the electrification of railroads, but stated that the picture had changed within a very few weeks; that it is now possible for all interested in the electrification of steam railroads to join hands and go forward with an unanimous mind with the thought of honest endeavor to bring to railroad electrification what is best for it from every standpoint.

Addresses were read from Honorable Herbert Hoover, Secretary of Commerce, and C. H. Markham, President of the Illinois Central Railroad. The speakers of the evening were: Edwin M. Herr, President of the Westinghouse Electric & Manufacturing Company: Gerard Swope, President of the General Electric Company: Paul Spencer Clapp, Department of Commerce, Washington, and Robert J. Cary, General Counsel of the New York Central Lines. All of these addresses are printed in full elsewhere in this issue of the JOURNAL.

In closing the meeting, President Osgood said, "I ask you to take home with you the thought that we have opened the way for a new situation in our efforts for the benefit of the nation. Let us see that we work together and, as we have done in the past, deliver the goods."

Report of Committee of Tellers on Election of Officers

To the President,

American Institute of Electrical Engineers

DEAR SIR:

This committee has carefully canvassed the ballots cast for officers for the year 1925-1926. The result is as follows:

Total number of ballot envelopes received		5454
Rejected on account of bearing no identifying name on outer envelope, according to Art. VI, Sec. 34, of the Constitution	50	
Rejected on account of voter being in arrears for dues on May 1, 1925, as provided in the Constitution and By-laws	136	
Rejected on account of ballot not being enclosed in inner envelope, or being improperly marked, or on account of inner envelope or ballot bearing an identifying name, according to Art. VI, Sec. 34, of the Constitution	208	
Rejected as duplicate ballots	31	
Rejected on account of having reached the Secretary's office after May 1, according to Art. VI, Sec. 34, of the Constitution	16	441
Leaving as valid ballots		5013

These valid ballots were counted, and the result is shown as follows:

FOR PRESIDENT

M. I. Pupin	4975
Blank	38

FOR VICE-PRESIDENTS

District	
No. 2 *Middle Eastern*	
Arthur G. Pierce	4874
*T. H. Schoepf	76
Blank	63
No. 4 *Southern*	
W. E. Mitchell	4928
Blank	85
No 6 *North Central*	
H. S. Sands	4926
Blank	87
No. 8 *Pacific*	
P. M. Downing	4929
Blank	84
No. 10 *Canada*	
W. P. Dobson	4926
Blank	87

FOR MANAGERS

M. M. Fowler	4731
E. C. Stone	4712
H. A. Kidder	4529
Ross B. Mateer	713
*E. B. Meyer	127
Blank	227

*Candidates who had previously requested that their names be withdrawn.

For Treasurer

George A. Hamilton........................ 4912
Blank.................................... 101

Respectfully submitted,

R. R. Kime, *Chairman* J. W. Nostrand
A. F. Hamdi W. G. Freeman
Committee of Tellers

Date May 13, 1925

Report of Committee of Tellers on Amendments to the Constitution

May 11, 1925

To the Board of Directors,
American Institute of Electrical Engineers

Gentlemen:

This committee has canvassed the ballots cast on the amendments to the Constitution submitted to the membership in a circular letter dated February 25, 1925, and the result is as follows:

Total number of envelopes received................		7080
Of these the following were rejected in accordance with the Constitution and By-laws, for the reasons given below:		
Received from members whose dues were in arrears on May 8, 1925..............................	198	
Number of envelopes received after May 8, 1925....	12	
Received without identifying name on outside of envelope, or because of enclosure in envelopes bearing no indication of contents, etc.......................	124	
Duplicates..	2	
Total invalid ballots..........................	336	
Leaving as valid ballots..........................		6744

These valid ballots were counted and the result is as follows:

Subject of Amendment	In favor of	Against	Scattering & Blank
Objects of Institute...........	6456	251	37
Qualifications for Membership..	6532	177	35
Resignations and Expulsions....	6505	198	41
Admission Fees...............	6106	597	41
Annual Dues.................	5224	1461	59
Life Membership.............	6502	193	49
Exemption from, and Remission of Dues................	6544	143	57
Officers—Eligibility and Vacancies........................	6563	118	63
Election of Officers............	6527	151	66
Change in Titles of Officers.....	6587	127	30

The total membership of the Institute on May 1, 1925, was 17,318. It will, therefore, be evident from the above that more than 20% of the total membership voted, and that more than 75% of those who voted were in favor of the adoption of each amendment and, therefore, under the provisions of the Constitution all the proposed amendments are adopted, and go into effect June 15, 1925.

Respectfully submitted,

R. R. Kime, *Chairman* A. F. Hamdi
W. G. Freeman E. A. Merwin
J. W. Nostrand
Committee of Tellers

Report of Board of Directors for the Year Ending April 30, 1925

The Annual Report of the Board of Directors of the A. I. E. E. was presented at the Annual Business Meeting of the Institute held in New York, Friday evening, May 15, 1925.

This report consisted of a brief summary of the principal activities of the Institute during the year, including abstracts of various reports submitted by officers and committees, covering their respective branches of work. The more important matters referred to in it have been or will be covered in much greater detail in the Journal, and, therefore, the report will not be published in full here. Any member of the Institute may obtain it in pamphlet form upon application to the Secretary.

The growth in Institute membership during the year is indicated in the following tabulation:

	Honorary Member	Fellow	Member	Associate	Total
Membership, April 30, 1924.......	6	594	2,359	13,496	16,455
Additions:					
Transferred..........		11	64		
New Members Qualified..............		1	80	1,901	
Reinstated..........		3	7	61	
Deductions:					
Died...............	2	7	13	62	
Resigned...........		3	23	316	
Transferred..........			10	65	
Dropped...........		2	28	734	
Membership, April 30, 1925.......	4	597	2,436	14,281	17,318

Net increase in Membership during the year.................. 863

The activity of the Sections and Branches during the year and the growth in the number of these organizations, also in the number of meetings held by them and in the aggregate attendance, are shown in the following statement:

	For Fiscal Year Ending			
	May 1 1919	May 1 1921	May 1 1923	May 1 1925
Section				
Number of Sections......	34	42	46	49
Number of Section meetings held.............	217	303	344	386
Total Attendance........	25,837	37,823	46,672	49,029
Branches				
Number of Branches.....	61	65	68	82
Number of Branch meetings held.............	156	443	503	548
Attendance............	6,441	21,629	26,893	27,603

The report includes a complete financial report, including details of the Assets and Liabilities of the Institute.

Comments Requested on Preliminary Draft of Standards

In the work of revision of the A. I. E. E. Standards, another section has been brought by the Working Committee to a point where the comments of the Institute membership in general are desired. The new section is

No. 9. Induction Motors and Induction Machines in General.

This draft of the Standards has been prepared by a working committee in whose appointment every effort has been made to select the men, from all branches of the art, most competent to contribute directly to the development of an accurate and generally acceptable set of Standards. Copies of the above are now available, without charge, and all who are interested are requested to apply to Institute headquarters.

In order that this section may be revised and adopted as an Institute Standard this spring, it will be necessary for all comments to be sent in at once. Write direct to H. E. Farrer, Secretary Standards Committee, 33 West 39th St., New York, N. Y.

Doctor Michael I. Pupin

PRESIDENT-ELECT OF THE A. I. E. E.

As announced in the report of the Committee of Tellers, published elsewhere in this issue Doctor Michael I. Pupin of Columbia University, New York, N. Y., has been elected President of the American Institute of Electrical Engineers for the year beginning August 1, 1925.

Michael Idvorsky Pupin was born in 1858 in Idvor, Banat, which now forms part of the Kingdom of the Serbs, Croats, and Slovenes.

After completing his education at the village school and displaying unusual talents he was sent to Prague, Czecho-Slovakia to continue his education in studies preparatory for higher education. He ran away from Prague and came to America; landed in New York in 1874, and after five years struggle for existence saved up enough money to enter Columbia College, where he graduated with high honors in 1883, with a B. A. degree.

He then returned to Europe for the purpose of taking up graduate work in physics and mathematics at the University of Cambridge, England, and at the University of Berlin, Germany and after earning a Ph. D. at Berlin returned to Columbia University, where, together with the late Professor F. B. Crocker in 1889 as instructor in mathematical physics he started the Electrical Engineering Department.

Michael I. Pupin
PRESIDENT-ELECT OF THE A. I. E. E.

Doctor Pupin's earliest work was devoted to the study of the passage of electricity through rarefied gases and several papers concerning the results were published. In 1892 he took up the subject of electrical resonance which resulted in the invention of the employment of tuned circuits for selective electrical reception of signals. Also resonance analysis by tuned circuits was worked out by him, employing for means of selectivity by tuning, circuits of variable inductance and variable capacity. The resultant inventions were acquired by the American Marconi Wireless Company in 1902. They are now universally used in radio broadcasting.

In 1895-6 he developed a method of rectifying both low and high-frequency oscillations so as to make them detectable by d-c. instruments. The rectifier consisted of a polarized electrolytic cell, and it was then clear to him that rectification was a very important element in wireless telegraphy, an opinion which has been justified to a remarkable degree by the developments in the wireless art which have taken place within the last twenty-five years. In February 1896 he invented a method of rapid X-ray photography by laying a fluorescent screen upon the photographic plate, a method now universally employed. In March of the same year he discovered secondary X-ray radiation.

The subject of electrical wave transmission over long conductors began to occupy Doctor Pupin's attention as early as 1894, and his earliest work in this direction was chiefly mathematical, and he found a general solution of the great problem of LaGrange, namely, the problem of analyzing the motion of a stretched weightless string carrying at equal intervals of its length equal masses. The solution of this purely dynamical problem suggested immediately its applicability to transmission of electrical waves over telephone wires and it was obvious that the introduction of suitable inductance coils at predetermined distances along the telephone line would greatly improve the efficiency of transmission by making it possible to transmit the electrical energy carrying the articulate voice of man by high potential and small current, thus reducing ohmic resistance losses on the line. This invention was acquired by the American Tel. & Tel. Co. January 1901. The practical applicability of this invention required the knowledge of making highly efficient inductance coils, using very finely laminated iron cores and Pupin devoted a study of several years to the investigation of these iron losses, resulting in the design of the toroidal coil, known all over the world as the Pupin coil. Pupinizé, pupiniziert, and pupinizatione are new words in French, German, and Italian, describing the Pupin method of telephone cable construction adopted at the Paris conference of 1924 for international telephone communication.

During the war, Doctor Pupin served on several national committees connected with war work, particularly the National Advisory Committee for Aeronautics and the National Research Council, and with a Government committee for submarine detection, which had its headquarters at New London. Dr. Pupin and his staff were engaged in developing a method of submarine detection by means of very high-frequency sound waves sent out by a panel of vibrating quartz plates. Since the wave length of these sound waves in water is small in comparison with the dimensions of the vibrating plate, the sound waves were concentrated in a beam similar to the light beam sent out by a searchlight. The detection consisted in receiving an echo from a submerged submarine. In prosecuting this work Doctor Pupin developed a multi-step vacuum tube amplifier which is free from internal noises and which does not transmit low frequency under-water noises.

Doctor Pupin is a member of the National Academy of Sciences, of the National Research Council, of the Serbian Academy of Sciences, and of many other learned societies, and has been a Fellow of the American Institute of Electrical Engineers for many years. In 1920 he was awarded the Edison Medal. He has also received from the French Academy the Hebert Prize in Physics, and from the Franklin Institute the Carson Gold Medal, also the Gold Medal from the Social Science Association and the gold medal of honor of the Radio Institute of America. He also holds honorary degrees of Doctorof Science from Columbia, and Princeton Universities; the honorary degree of Doctor of Laws from Johns Hopkins, New York University and Muehlenberg College; and several other honorary degrees from American Universities. He is now Professor of Electro-Mechanics, Columbia University, and Director of the Phoenix Research Laboratory of the same university.

International Electrotechnical Commission at The Hague

Meetings of nine of the Advisory Committees of the International Electrotechnical Commission were held at The Hague April 16th to 23rd, 1925. Delegates were present from thirteen countries. Inasmuch as the meetings included seven working days, with two sessions in parallel on most of the days, a great deal of ground was gone over.

The meeting was characterized by a spirit of harmony, and the evident desire of all delegates to make the meeting as fruitful as possible.

An innovation which was tried at this meeting was that of having reports by experts on subjects of fundamental importance in connection with the work to be undertaken by the Advisory Committees. These reports, and the discussion which followed them, quite in the manner of technical sessions of the A. I. E. E., were very useful in paving the way for the standardization work which followed.

Expert reports were presented from America by N. W. Storer on the Discrepancies between the Present Methods of Testing Traction Motors and the Actual Working Conditions, and by G. Faccioli on the Formation of Sludge as Influenced by the Construction of Transformers. The names of the Advisory Committees, together with the names of the individuals who were designated to preside at their meetings were as follows:

Advisory Committee on Nomenclature...... Dr. Mailloux
Rating............ Prof. Feldman
Symbols........... Prof. Janet
Prime Movers...... Mr. Semenza
Lamp Caps and Sockets.................... Dr. Sharp
Standard Voltages........................ Mr. Brylinski
Traction Motors.......................... Dr. Huber Stockar
Insulating Oils.......................... Dr. Sharp

Rules and Regulations for High Voltage Overhead Transmission Lines................ Dr. Brylinski

Important among the decisions which were reached were the following:

Limiting temperature rise of rotor field windings of large synchronous machines (by resistance); steam turbine Class B insulation, 90 deg.; salient pole machines, 80 deg.

Limiting temperature rise for stator windings with imbedded detectors between coils, Class A insulation, 60 deg.; Class B insulation, 80 deg.

It was recommended that measurement of efficiencies by summation of losses should be standard.

Program of work was decided on for the Advisory Committees on Prime Movers, which is to deal with (1) hydraulic, (2) steam, and (3) internal combustion machines.

The final standardization of the Edison screw base and socket dimensions was deferred, awaiting a report of a technical committee of manufacturers which is promised to be given within a year.

As standard low voltages 220 and 230 were adopted, together with the half and double of each of those values, and also the voltage occurring between each line and neutral of a three-phase four-wire system, having 220 or 230 between lines; namely, 127 volts and 133 volts.

A set of standard high voltages was also agreed upon.

With respect to traction motors, it was agreed that there shall be both a continuous rating and a one-hour rating, and that there shall be an excess load test, as a mechanical and commutation test. Limiting temperature rises were agreed upon and also ambient temperature of reference.

The Committee on Insulating Oils agreed upon a program for conducting comparative tests in various countries to form a basis for the adoption of specifications.

The meetings of the Committees were held in the Royal Institute of Engineers and the Dutch engineers who were the hosts were most efficient in making arrangements for the rapid furtherance of the work and most successful in making the stay of the delegates in The Hague a very enjoyable one.

A. I. E. E. Directors Meeting

The regular monthly meeting of the Board of Directors of the American Institute of Electrical Engineers was held at Institute headquarters, New York, on Friday, May 15, 1925.

There were present: President Farley Osgood, Newark, N. J.—Vice-Presidents William F. James, Philadelphia; Harold B. Smith, Worcester, Mass.—Managers A. G. Pierce, Cleveland; W. K. Vanderpoel, Newark, N. J.; H. P. Charlesworth, New York; John B. Whitehead, Baltimore—Secretary F. L. Hutchinson, New York.

The Board ratified the approval by the Finance Committee of monthly bills amounting to $23,331.18.

A report was presented of a meeting of the Board of Examiners held May 11, and the actions taken at that meeting were approved. Upon the recommendation of the Board of Examiners the following actions were taken upon pending applications: 137 Students were ordered enrolled; 145 applicants were elected to the grade of Associate; 5 applicants were elected to the grade of Member; 7 applicants were transferred to the grade of Member; 2 applicants were transferred to the grade of Fellow.

The annual report of the Board of Directors for the fiscal year ending April 30, 1925, as prepared by the Secretary, was presented and accepted for presentation at the Annual Business Meeting of the Institute during the evening of the same day. The annual report of the Treasurer for the fiscal year ending April 30, 1925, was presented, accepted, and ordered filed.

The annual reports of various standing committees (exclusive of the technical committees, whose reports will be presented at the Annual Convention in June), abstracts of which were incorporated in the Board of Directors' report, were presented, received, and ordered filed for reference, particularly by the chairmen of the incoming committees of the next administration.

On account of the increasing development and popularity of the regional meetings, and for the purpose of furthering this development, the Board voted to discontinue the Spring Convention of the Institute.

The Committee on Award of Institute Prizes reported on the award of the First-Paper Prize and of the Transmission Prize for 1924, as announced elsewhere in this issue.

Upon the recommendation of the Committee on Applications to Marine Work, the Board voted to approve the publication of a revised edition of the Marine Rules of the Institute.

Upon the recommendations of the Standards Committee, the Board approved the adoption of the following as A. I. E. E. Standards: "Standards for Direct and Alternating-Current

Fractional Horse power Motors" No. 10; "Illuminating Engineering Nomenclature and Photometric Standards"—No. 37.

A suggestion for the appointment of an Institute Committee on Nomenclature was considered, and the Board voted that a small continuing committee be appointed as a subcommittee of the Standards Committee, for the purpose of recommending names for concepts in electrical science and engineering.

The Board accepted a bequest of the late Sarah J. Farmer to the Institute of an oil painting of her father, Moses G. Farmer, and upon request of the officers of the Boston Section, directed that the portrait be assigned to the custody of the Boston Section.

Upon the recommendation of the Joint Conference Committee, consisting of the presidents and the secretaries of the four Founder Societies, the Board voted to appropriate $125 toward the publication of the International Critical Tables.

In view of the fact that the U. S. Civil Service Commission has adopted the term "Engineman" in place of "Engineer" when referring to positions the duties of which are the operation, maintenance, or repair of stationary or moving engines, and upon the recommendation of the Joint Conference Committee, the Board voted that this practise be followed in the Institute's publications, and that publicity be given to this action.

A communication was read from Mr. P. F. Rowell, Secretary, Institution of Electrical Engineers (Great Britain), presenting to the Institute for its Library a copy of "The Roll of Honour of the Institution of Electrical Engineers." The Board accepted this memorial volume with an expression of appreciation of its worth and of the action of the Institution in presenting a copy to the A. I. E. E.

In accordance with Section 37 of the constitution, the Board considered the appointment of a Secretary of the Institute for the administrative year commencing August 1, 1925; and Secretary F. L. Hutchinson was reappointed, with the added title and duties of Executive Manager.

Other matters of importance were discussed, reference to which may be found in this and future issues of the JOURNAL.

ENGINEERING FOUNDATION

DINNER TENDERED MR. SWASEY

The Engineering Foundation began its second decennium at its regular quarterly meeting May 14. This fact was marked by a subscription dinner to Ambrose Swasey, the Founder, given by the present and former members of the Foundation, the Trustees of United Engineering Society and the officers and directors of the American Society of Civil Enginers, American Institute of Mining and Metallurgical Engineers, American Society of Mechanical Engineers, American Institute of Electrical Engineers. Forty-five persons were present in the private dining-room of the Union League Club of New York.

After dinner, Vice-Chairman Edward Dean Adams, who presided in the absence of Chairman Stillwell, presented Mr. Swasey, on behalf of the Presidents and Secretaries of the four Societies and the present and former members of Engineering Foundation, in expression of appreciation for his gifts to the Foundation, with the following testimonial:

Engineering Foundation at the beginning of its second decennium and on behalf of the American Society of Civil Engineers Am. Inst., Mining and Metallurgical Engineers, American Society of Mechanical Engineers, American Institute of Electrical Engineers declares affection, pledges loyalty and expresses gratitude to AMBROSE SWASEY, FOUNDER, for his vision and his gifts for the furtherance of research and the good of mankind.

High esteem is witnessed by the signatures hereto affixed May 14, 1925.

The testimonial, on vellum, beautifully engrossed and illumined, its pages bearing the signatures of the forty-four men mentioned, was handsomely bound in a small book.

On behalf of the Foundation Board, Vice-Chairman Adams delivered to Past-Chairman Charles F. Rand an exquisitely printed and bound copy of a resolution adopted at the annual meeting in February in appreciation of his five years' service,

"RESOLVED: that the Engineering Foundation Board records its high appreciation of the long, active and able service which Charles F. Rand has rendered to Engineering Foundation and the valuable contribution which he has thus enabled the Foundation to make to the Profession of Engineering and its related industries. Through his service as Chairman for five years, Engineering Foundation has become well known throughout our country and in other lands. Through him substantial contributions have been added to the endowment funds."

After the business meeting, President J. V. W. Reynders, of American Institute of Mining and Metallurgical Engineers, voiced the sentiments of the four Founder Societies toward Mr. Swasey for his vision and generosity in making possible the establishment of Engineering Foundation.

The evening was closed by Dr. Frank B. Jewett, a former Vice-Chairman of the Foundation, who gave an address on "Permalloy Cables for Submarine Telegraph," illustrating by a motion picture the landing at the Azores of the first cable in which this new allow was used.

In response to the honor conferred upon him, Mr. Swasey's remarks were, in part, as follows:

Mr. Chairman, Members of the Board, dear friends, one and all:

As always, it is a pleasure to be with you and I only wish it were possible for me to tell you how much I appreciate your kind words relative to my interest in this Foundation and this token of your appreciation. It seems to me, however, that in view of all that you have done in the past and are still doing, it is you who should be complimented rather than I.

Ten years is a long time to look ahead, but we all know that the years pass quickly and a decade slips away almost before we know it. With me, as with our honored chairman, it is difficult to realize that nearly eight such periods have already passed or more than one-half of the centuries since the time when our great republic was founded.

In starting out into new fields of endeavor, especially those which earnestly appeal to us, we are apt to feel that much more can be accomplished in a given time than is actually possible. We forget that many, if not all, of the great movements for the good of mankind have had their beginnings in a modest way and only after many decades of untiring work and devotion, have become great and worthy institutions. The four national engineering societies, which we often call the Founder Societies, were organized with modest beginnings and small memberships, but now their combined membership is more than 50,000 and the engineering profession has reached a higher plane than was ever dreamed of when these Societies were established. This marvelous growth in membership and influence of the engineering profession may, to some extent, be credited to the general advancement of arts and sciences throughout the world; but if it were not for the noble men of science and engineering of those days, who devoted the best that was in them to the formation and building up of these great Societies, I fear they would be far from occupying the high positions which they hold today.

The limited means at the disposal of the Foundation necessarily restrict the scope of the work. Still, much has been accomplished and I feel that the officers are to be congratulated upon the high quality of the research work they have undertaken and carried through to completion. I am especially appreciative of the effort that is being made greatly to increase the resources of the Foundation; and may I here express myself as especially gratified for the provision which our good friend, the late Henry R. Towne, has made for the carrying on and extension of the work. While, under the circumstances, it may not be possible to accomplish as much as we would like, yet I think today the biblical injunction is as true as it was of old that, "He that is faithful over a few things shall be made ruler over many things."

I was never more hopeful of the success of the Foundation than I am at the end of the first decade.

National Academy of Sciences Elects New Life Members

The National Academy of Sciences, at its annual meeting ending April 29, elected to life membership, Elmer A. Sperry, President of the Sperry Gyroscope Company and a member of the A. I. E. E. since 1884. Mr. Sperry is best known for his gyro-compass ship stabilizers and high-intensity searchlights.

William D. Coolidge, Assistant Director, Research Laboratory, General Electric Company, also became a member in recognition of his development of the X-Ray tube.

FIRST WOMAN MEMBER ALSO INSTALLED

Among other members elected at the meeting was Miss Florence R. Sabin, physiologist of John Hopkins Medical School of Baltimore, Md. By this action science in America has, for the first time, officially recognized the work of a woman.

Regional Meeting at Swampscott Great Success

Papers of the highest quality and enjoyable recreational features assured the success of the regional meeting held June 7, 8 and 9, at Swampscott, Mass. There was a registered attendance of 370 and all were highly pleased. Very thorough preparations had been made by the committees in charge and the Northeastern Geographical District deserves much credit for the success of the meeting.

The entertainment program started on Thursday evening, May 7, with a dinner at the New Ocean House; this was followed by a dance. On Friday evening a dinner was held at which there were two speakers, Dr. Elihu Thomson and Johnson O'Connor. There was also a sleight-of-hand performer and a vocalist. Dr. Thomson spoke on the late advances in physics and electricity, while Mr. O'Connor told of some of the interesting studies connected with the personnel problems of a large organization.

Many of the visitors enjoyed golf during the afternoons. On Friday and Saturday afternoons two daring groups put to sea in a small motor boat to go fishing. Reports say that many large fish got away but everyone was glad when the fishermen, themselves, returned safely.

The inspection trips were well attended, the main trips being to the Weymouth Station of the Edison Electric Illuminating Company of Boston, the Lynn Works and the River Works of the General Electric Company.

The ladies who were present enjoyed several automobile rides along the shore line.

The technical sessions drew a large attendance and produced much good discussion. H. B. Smith, vice-president of the Northeastern District opened the first session on Thursday morning. He introduced Farley Osgood, President of the Institute, who made a short address on the duties of the engineer. B. W. St. Clair, chairman of the local meeting committee, then took the chair.

The first paper was entitled, "Overvoltages on Transmission Systems Due to Dropping of Load" and was presented by E. J. Burnham. This was followed by "Sleet and Ice on Transmission Lines," by C. R. Oliver; "Electro-Mechanical Problem Analyzer," by C. A. Nickle, and "Losses in Iron Under the Action of Superimposed A-C. and D-C. Excitation," by O. E. Charlton and J. E. Jackson. Those discussing these papers were J. Reutter, H. C. Don Carlos, H. W. Smith, W. F. Dawson, L. W. W. Morrow, J. Roubicek, Farley Osgood, H. S. Knowlton, R. E. Argersinger, J. A. Johnson, M. J. Lowenberg, C. A. Worcester, R. D. Booth and W. R. Weeks.

On Thursday afternoon, the session was presided over by C. A. Adams. Papers were presented as follows: "Tap Changing Under Load," by H. C. Albrecht; "Voltage Control Obtained by Varying Transformer Ratio," by L. F. Blume; "Changing Transformer Ratios Without Interrupting the Load," by M. H. Bates; "Universal-Type Motors," by L. C. Packer; "A Two-Speed Salient-Pole Synchronous Motor," by R. W. Wieseman, and "Short-Circuit Currents of Synchronous Machines," by R. F. Franklin. The discussors were B. G. Jamieson, H. W. Smith, A. H. Kehoe, H. R. Wilson, W. L. Smith, S. W. Ashe, H. W. Hills, W. F. Dawson, F. W. Gay, C. A. Adams, J. C. Damon, F. L. Fairbanks and C. M. Laffoon.

At Friday morning's session W. A. Del Mar presided. Five papers were presented, namely: "Cooperative Course at the Massachusetts Institute of Technology," by Professor W. H. Timbie; "Oil-Filled terminals for High-Voltage Cables," by E. D. Eby; "Cable Joints," by E. W. Davis and G. J. Crowdes; Effect of Repeated Voltage Application on Fibrous Insulation," by F. M. Clark, and "Education in Industry," by S. W. Ashe. Those contributing discussion were H. B. Smith, W. L. Smith, J. C. Clendenning, C. A. Adams, A. J. Krupi, T. B. Rutherford, V. Bush, A. P. Thomas, Mario Pirelli, F. A. Brownell, C. F. Hanson, C. F. Hood, A. H. Kehoe, D. A. Dooley, E. S. Mansfield and H. A. Dallis.

On Saturday morning A. E. Knowlton was in the chair. The following papers were presented: "Calibration of Wavemeters," by James K. Clapp; "Predetermination of Self-Cooled Oil-Immersed Transformer Temperatures," by W. H. Cooney; "Studies of Time Lag of Needle Gaps," by K. B. McEachron and E. J. Wade; "Recent Improvement in A-C. Indicating Instruments," by S. H. Hoare; "Measurement of Electrical Output of Large A-C. Turbo-Generators," by E. S. Lee, and "Temperature Errors in Induction Watthour Meters," by I. F. Kinnard and H. T. Faus. These were discussed by C. H. Dagnall, H. B. Smith, L. W. W. Morrow, W. L. Smith, H. W. Octinger, J. A. Johnson, W. H. Pratt, F. V. Magalhaes, C. H. Ingalls, C. G. Brown and B. W. St. Clair.

Franklin Medal Awarded to Professor Elihu Thomson

Professor Elihu Thomson, one of the founders of the General Electric Company and director of the company's research laboratory at Lynn, Mass., was awarded the Franklin Medal and certificate of honorary membership in the Franklin Institute at a meeting held May 20th at Philadelphia.

Previous to the presentation of the medal to Professor Thomson, "In recognition of his pioneer work in the field of electricity and electrical engineering, and his numerous inventions in these fields," E. W. Rice, Jr., honorary chairman of the board of directors of the General Electric Company, reviewed Doctor Thomson's many achievements and inventions in the field of electricity, stating that it was with the keenest delight he had learned that he, Doctor Thomson, was to be the recipient of the medal this year, and that the honor of participating in the event was greatly appreciated.

Annual Meeting of the American Society for Testing Materials

The twenty-eighth Annual Meeting of the American Society for Testing Materials will be held during the week of June 22, at the Chalfonte-Haddon Hall, Atlantic City, N. J. The committee in charge has so arranged the program as to leave afternoons open for special committee work and recreation. Technical sessions will include the work of research, testing and nomenclature on purchase specifications, corrosion; metals at high temperature; cement and concrete, road materials, roofing materials, textiles and miscellaneous. The same plan obtaining in the past for the distribution of preprints will be continued, and they will be mailed upon request as they become available.

Association of Mechanical and Electrical Engineers of Porto Rico Newly Organized

The Association of Mechanical and Electrical Engineers of Porto Rico has just been organized. An important qualification for admission to this Association is membership in either the A. I. E. E. or A. S. M. E., and it is anticipated that this stipulation will greatly stimulate the growth of the two memberships in Porto Rico. The Constitution was adopted as of April 10, 1925 and the roster of charter members includes 12 members of the A. S. M. E. and 10 of the A. I. E. E. Any member of the Institute visiting Porto Rico, interested in getting in touch with local engineers, should communicate with the chairman or secretary of the new organization. *Chairman*: H. E. Setchell, c/o University of Porto Rico, Mayaguez, P. R., *Secretary*: H. L. Talbot, Box 368, San Juan, P. R.

Dedication of Edison Tablet

In the presence of the entire Edison family, the Governor of New Jersey, the mayors of a number of New Jersey and New York cities, the president of Princeton University, chief executives of companies important in the electrical industry and practically all the surviving early associates of the great electrical genius, Mrs. Thomas Alva Edison, on May 16th, unveiled the beautiful bronze tablet in Menlo Park, New Jersey, marking the spot where Thomas A. Edison began his experimental achievements and conceived and perfected nearly all of his inventions. The inscription on the tablet reads as follows:

> On this site—1876-1882—Thomas Alva Edison began his work of service for the world to illuminate the path of progress and lighten labors for mankind. This tablet is placed by the Edison Pioneers to attest the gratitude of the industries he did so much to create.

The address of welcome was made by Charles L. Clark, President of the Edison Pioneers, and the service of Dedication was conducted by John W. Lieb, Vice-President of the New York Edison Company. Other addresses were given by Hon. George S. Silzer, Governor of the State of New Jersey, Doctor John G. Hibben, President of Princeton University, Edwin W. Rice, Jr., Honorary Chariman of the Board, General Electric Company and Samuel Insull, President, Commonwealth Edison Company of Chicago.

AMERICAN ENGINEERING COUNCIL

GREAT ACTIVITY IS PLANNED FOR FUTURE ACCOMPLISHMENT

At a meeting of its Administrative Board, at the Philadelphia Engineers Club, May 8-9, the American Engineering Council voted to undertake what may be described as the first exhaustive investigation of the aircraft situation ever made in this country. By a special committee the various aspects of the problem, both military and civil, will be thoroughly reviewed and it is estimated that the task will involve a full year's work at an estimated expenditure of \$50,000. The Board's action is prompted by the report of the Council's Aeronautics Committee, of which Prof. J. W. Roe is chairman, warning that the present confused situation in the aeronautical field is a national menace both as to military preparedness and commercial development. The present Committee on Aeronautics was dismissed and a new commttee to carry out this work of investigation under the direction of the Council's Administrative Board, will be appointed by the president, Honorable James Hartness. Work will commence at once in the arrangement for funds and the mapping out of a proper course of procedure.

The Board adopted the report of it's Committee on U. S. Government Reorganization, supporting the Mapes bill in the carrying out of the plan of the Congressional Committee on Reorganization. The Council will discontinue its effort toward the establishing of Assistant Secretaryships of Public Architecture and Public Construction, adhering to the proposal for the establishment of a Division of Public Works and a Division of the Public Domain. A bill incorporating the Council's proposal, is being prepared for presentation to Congress. The Jone-Wyant amendment to the Mapes bill, providing for four secretaries instead of two, will not be pressed. The next session of Congress will have before it the Mapes bill and the bill to be sponsored by the Council.

The Administrative Board decided to cooperate in the execution of a city planning scheme for the District of Columbia, in which the Washington Society of Engineers will take a leading part. A City Planning Committee will be appointed by the Council to work with similar committees of the member societies. Charles T. Main of Boston was appointed to represent the Council in aiding the War Department's preparedness plans as they relate to construction work. Mr. Main is the Council's present representative on the Civilian Conference Committee.

The resignation of Rudolph P. Miller, of New York, as the Council's representative on the National Board for Jurisdictional Award, effective August 1, was accepted. In a report to the Board, Mr. Miller asserted that strikes, due to trades union disputes in the building industry, were rapidly being eliminated as the result of the Jurisdictional Board's effort, and were being generally respected by labor.

A large and enthusiastic dinner gathering was held at the Philadelphia Engineers Club on the evening of May 8. L. W. Wallace, executive secretary, reported that the Council was making steady progress in constructive activity and influence. Dean Dexter S. Kimball, of Cornell, vice-president of the Council, appealed for greater unity among engineers in furthering the work of the Council.

Gardner S. Williams of Ann Arbor, Mich., vice-president, presided over the Board's sessions in the absence of President James Hartness, who is still unable to attend.

PERSONAL MENTION

Fred M. Rosenzweig has left the Regan Safety Devices Company, Niagara Falls, N. Y., returning to New York City to assume the managership of an electrical manufacturing firm.

John F. Maxwell, who was associated with the Stone & Webster, Inc., as Electrical Engineer, has made new affiliations with the Edison Electric Illuminating Company, also of Boston.

E. R. Kulka has resigned from the presidency of the Besco Electric Manufacturing Corp., to become general manager and chief engineer of the C. D. Wood Electric Company of New York.

L. R. Parkerson, formerly with the Consolidated Gas Company of New Jersey, Long Branch, is now engaged with the Central Hudson Gas & Electric Company, Poughkeepsie, New York.

Rudolpho Westerman, Electrical Engineer, Central Alto Cedro, Oriente, Cuba, has removed to Miami, Florida, where he will be identified with the Biscayne Electric Supply Company.

Price L. Rogers is no longer consulting engineer for H. Berkeley Hackett, Philadelphia, but has joined the firm of Messrs. Ritcher & Eiler, Architects, Reading, Pa.

George W. Quentin recently resigned from the Duquesne Light Company to take charge of sales to steel mills in the Pittsburgh district for the American Blower Company.

G. E. McLean, formerly of the Westinghouse Electric & Mfg. Company, East Pittsburgh, Pa., is now in the Electrical Engineering Department of the Commonwealth Power Corporation, Jackson, Michigan, having recently made this new connection.

Louis M. Meckler has resigned from the duties of distribution engineer for the Public Service Electric & Gas Company of Newark, N. J., and is now sales Engineer for the W. N. Matthews Corporation, 30 Church Street, New York City.

Harvey P. Sleeper formerly protection engineer for the Duquesne Light Company of Pittsburgh, Pa., is now associated with the Public Service Electric and Gas Company in like capacity, with headquarters in the Terminal Building, Newark, N. J.

Roger H. Bryant has been appointed electrical engineer on the staff of the Worcester District Engineer of the American Steel and Wire Company, Mass., and has removed from Wilkinsburg, Pa., to assume these new duties, in Worcester, Mass.

Ernest F. Cushman, previously chief operator for Price Brothers & Company, Kenogami, P. Q., Canada, has accepted a new position with the Idaho Power Company, Boise, Idaho, in their Department of Substations.

E. A. Wagner, of the Fort Wayne Section on May 8, 1925, addressed the regular meeting of the Engineering Society of Tri State College, Angola, Indiana. His subject was *Transformers.*

Harry Farquhar has resigned from the Service Dept., General Electric Company, Oakland, Calif., to become manager of the Electric Repair & Equipment Company, San Francisco, California.

David MacNaughton, who was local manager of the Columbus, Indiana, electric utility under the Interstate Public Service Company of Indiana, has recently left them to join the Minnesota Power and Light Company, Duluth, Minn., in power sales work.

Walter H. Sammis, previously of the Engineering Department of Charles H. Tenny & Company, has been appointed assistant to the vice-president of the Consumers Power Company, Jackson, Michigan, where he will have charge of all commercial light, heat and power sales for that entire system.

J. E. Thompson, assistant automatic chief of the Western Union Telegraph Company, has been transferred from Richmond, Va., to the Company's New York Cable Office. Mr. Thompson is also planning enrollment in an Electrical Engineering Course at Columbia University, as a Graduate Student.

H. A. Triplett, who, has been for the past four years, affiliated with the Duquesne Light Company of Pittsburgh, Pa. as assistant electrical engineer in charge of transmission and distribution, has resigned to accept position with the Schweitzer and Conrad Company, Inc., of Chicago.

B. B. Ramey, who has been for the past twelve years, with the Westinghouse Electric & Mfg. Co., as designing and section engineer at the East Springfield works, resigned on the 14th of April to take a position as electrical engineer with the Black & Decker Mfg. Co., Towson, Md.

William S. Higbie, who, for several years has maintained an engineering office at 114 Liberty Street, has discontinued this office to take up work with the Research Dept. of the American Smelting and Refining Company. His own manufacturing and other business interests will, however, be continued.

Leo A. Phillips, of Pittsburgh, Pa. has just accepted a commission as consulting engineer for the Pittsburgh Betagrande Mining Company, in the construction of a 2500-h. p. Diesel engine power-house, transmission line and mine equipment at Zacatecas, Mexico. Mr. Phillips starts his new work immediately.

T. A. Wood, formerly connected with the Cerro de Pasco Copper Corporation, Peru, S. A., has been appointed field engineer for the California Committee on the Relation of Electricity to Agriculture, and will work under Professor B. D. Moses of the Department of Agricultural Engineering, University of California, with offices at Davis, Calif.

James W. Dodge recently joined the engineering force of the Edison Electric Illuminating Company of Boston, and will operate in their Generating Department instead of the Central Station Engineering Department of the General Electric Company, Boston. Mr. Dodge will be located at North Weymouth, Mass.

Ira W. Fisk and Edw. A. Roberts, Members A. I. E. E., have formed a partnership under the name of Fisk & Roberts, 82 Beaver Street, New York, and are specializing in management and engineering service for transportation and power companies. Mr. Fisk who has withdrawn from the Beeler Organization, was formerly general manager of power and light properties at Springfield, Ill. Mr. Roberts still retains the management of the three railway companies serving Queens and Nassau Counties, New York.

Obituary

James B. Yeakle, Superintendent of the Fire Alarm Telegraph, City of Baltimore, died there April 24th, 1925, at the age of 83 years. Mr. Yeakle was educated through St. Johns Institute, Frederick, Md., the place of his birth, and for forty-four years was engaged in telegraph and allied service. He had been with the Fire Department service since 1902.

Howard A. Stofflet, who since 1910 has been identified with the Philadelphia & Reading Railway Company, died the latter part of April, 1925. Mr. Stofflet was born in a suburb of Easton, Pa., in the year of 1882. His early education was through the Bangor High School, the Bliss Electrical School of Washington, D. C., and Pratt Institute. July 1903, he entered upon his professional career with practical experience in power and lighting, wiring and motor generator repair work, in which field he continued until his appointment by the Philadelphia and Reading Railway Company, with whom he was at the time of his death. While with them, Mr. Stofflet organized their drawing room force and construction and maintenance forces, beside being actively engaged in design and shop manufacturing work. His supervision covered the entire electrical equipment of the Reading system, and for many years he was in charge of most important electrical work.

J. Harvey Anderson, of Hollywood, California, died April 1925. Born at Kaukauna, Wisc., February 12, 1896, Mr. Anderson, after passing through High School, entered upon an electrical engineering course at the U. S. Naval Electrical School, Mare Island, California. In 1913 he started with the Langstadt Meyer Company, Appleton, Wisc., but in 1914, left them to become wireman, stockman and estimator for the Herman Andrae Electric Company, Milwaukee. In 1917, he was appointed chief electrician of the U. S. Navy Destroyer forces in Europe, and upon his return to the States, in 1920, he was chosen chief electrician of the Fabricated Ship Corporation of Milwaukee. He also served the A. O. Smith Corporation of that city in like capacity from 1921 to 1922, subsequently becoming foreman of the F. E. Newbery Company of Los Angeles, California, with whom he was identified at the time of his death. The Fabricated Ship Company built thirteen mine planters for the government and Mr. Anderson had complete charge of the yard and ship installation, from the buying of the materials to the hiring of men and maintenance with a force of fifty men under him.

C. O. Poole, a pioneer in the electrical development of the West, died at Los Angeles, April, 1925. Mr. Poole was born at Lowell, Mass., and after his early common school education, entered upon a course with a business college in San Jose, California, with a private course in physics, mathematics and mechanical drawing. After a steady climb in varying capacities, Mr. Poole, in 1897, was elected Superintendent of the San Francisco Gas & Electric Company, successors to the Edison Light & Power Company, with whom he had served in charge of the Arc Light Station at San Francisco. He was chief engineer of the Navada California Power Company, the Southern Sierras Power Company, the Sierras Construction Company and the Pacific Power Company. Mr. Lighthipe was one of those who enthusiastically endorsed Mr. Poole for transfer to the grade of Fellow in the Institute, to which grade he was elected in 1913.

Charles W. Burrows, Vice-President of the Burroughs Magnetic Equipment Corporation and Fellow of the Institute since 1918, died on May 2, 1925. Mr. Burrows was born in Wilkesport, Ontario, on July 2, 1874. He graduated from Michigan with an A. B. in 1898 and in 1901 took his A. M.; in 1907 Ph.D. degree. In 1906 he joined the scientific staff of the Bureau of Standards at Washington, D. C., remaining with them until 1918. Mr. Burrows was one of the leading American authorities on magnetic testing of steel, to which work he devoted his time while with the Bureau of Standards and since 1918 as a consulting engineer. Among other inventions he perfected the magnetic permeameter, magnetic defectoscope and magnetic analyzer. Mr. Burrows became a Member of the Institute in 1914 and a Fellow in 1918.

August Kreusi, former engineer of construction of the General Electric Company, died at El Paso, Texas, May 7.

Born in Newark, New Jersey in the year 1876, Mr. Kreusi was graduated from Union College 1898, from that time until 1900 he was with the British Thomson-Houston Company in London. During the next two years he worked on electrical machine design for the General Electrical Company at Schenectady. From 1902 to 1906 he was engaged in the commercial development of the Curtis steam turbine, and until 1908 was in the railway engineering department, working on power house and substation design. Mr. Kreusi was made head of the construction engineering department of the General Electric Company when this department was established in 1908, and continued in that position until he obtained a leave of absence because of ill health in 1921. In 1923 he resigned but continued his work with the company as consulting engineer.

Major-General Edgar Russel, U. S. A., retired, died at his apartment, 1045 Park Avenue, this city, April 27, 1925, at the age of 63. General Russel was born at Pleasant Hill, Missouri, February 20, 1862. After a two years' course in the Missouri State University, including chemical and electrical laboratory work, he entered West Point Military Academy, from which he was graduated after a four years' course, in 1887. From 1893 to 1898, he was Instructor and Assist. Professor in their Department of Chemistry, which included practical experience in the installation of electrical appliances of all kinds and charge of the electrical plant and laboratory. In August 1898, he was appointed Captain and Signal officer of the United States Volunteers for construction and management of telegraph and telephone lines in Southern Luzon, P. I., in charge of the central office, power house and military telephone system of Manila. During the year 1900-1901, he was on duty with the cable ship "Burnside," laying cable in southern Philippine waters; in June 1901, he returned to the United States to assume duty as assistant in the office of the Chief Signal Officer, U. S. Army, Washington, D. C., in charge of the Telegraph Division, etc. with special duties in connection with the design and inspection of instruments and Signal Corps supplies.

He was brevetted for gallantry in action in Manila and at Calaacan, and on January 21, 1919, received the Distinguished Service Medal for his services in France. He was also decorated by the British and French Governments for his achievements in the World War. He was made Major-General in 1922 and that same year retired from the army, due to injuries sustained in service.

Major William H. Wiley, Treasurer of The American Society of Mechanical Engineers since 1884 and Associate of the Institute since 1888, died at his home, East Orange, N. J., May 2, 1925, in the eighty-third year of his age. Major Wiley was a native of New York City, in which he spent the greater portion of his life. At the time the Civil War broke out, he was attending the College of the City of New York; he immediately joined the Independent Corps of the New York Volunteer Light Infantry as first lieutenant. This Infantry formed the nucleus of what later became the Seventh Regiment; Major Wiley was elected president of the Seventh Regiment War Veterans. In the course of the Civil War, Major Wiley rose to the command of two companies of artillery, seeing most of his service in South Carolina, where he served with distinction. He was given special mention by General Gillmore "for efficient and able services during the siege and bombardment of Fort Sumter and Charleston, S. C." In 1864 he was retired as brevet major "for gallant and meritorious services." Despite his great activity in the publishing field, Major Wiley found time for many other interests. He was, for three years, a member of the township committee of East Orange, served three terms in Congress as representative for the State of New Jersey, was commissioner from New Jersey to the St. Louis Exposition and president of the International Jury of the Brussels Exposition in 1907, being decorated with the Order of Leopold by the King of Belgium. During the World War, he was chairman of the National Preparedness Committee of the A. S. M. E. was an active member of all four of the founder societies and also belonged to the American Association for the Advancement of Science.

Milan E. Bump, chief engineer for Henry L. Doherty & Company, New York, and former president of the National Electric Light Association, died May 5th, 1925, at Denver, Col. Mr. Bump was born at Rock Falls, Wis., March 18, 1881. His boyhood was passed in Spokane, Wash., where he received his early education in the public schools. In the fall of 1898, he entered the University of Wisconsin and was graduated therefrom with the degree of B. S. in electrical engineering in 1902. He immediately entered upon engineering work with the Washington Water Power Company, but in 1903 returned to Madison, Wis., to pursue his engineering studies and, incidentally, serve one year as instructor in electrical engineering at the University of Wisconsin. In 1904, Mr. Bump became associated with the Henry L. Doherty as the first cadet engineer of the Doherty training school, and until 1906 was engineer for the gas department of the Denver Gas & Electric Light Company, one of the first Doherty properties. Subsequent to 1909, he removed to Joplin, Mo., where he was instrumental in consolidating electric utilities of the lead and zinc district, and forming the Empire District Electric Company, of which he was treasurer and general manager. He also erected a large modern steam plant and a transmission system which covered the entire mining field. In 1910 was transferred to New York. After four years as vice-president of the N. E. L. A., he was elected to the presidency at the Chicago Convention and filled that office with ability and distinction. Mr. Bump joined the Institute in 1903. He was, beside, a member of the American Electric Railway Association, the American Electrochemical Society, the Society for the Promotion of Engineering Education, the Engineers' Club of New York as well as of many other technical and social organizations.

Arthur Jacob, of Hatch End, Middlesex, England, died there April 3rd, 1925, in the 57th year of his age. Born in Dublin, Ireland, May, 1867, Mr. Jacob received his first technical education through the Royal College of Science, Dublin. In 1889 he joined Dr. S. L. de Farranti F. R. S., then engineer-in-chief of the London Electric Supply Corp., Ltd., London and Deptford. Shortly thereafter, Mr. Jacob was made resident engineer of the Electricity Supply Co. for Spain, Ltd., at Madrid as well as for the British Thomson-Houston Co., Ltd., London, working on the conversion of the Dublin United Tramways over from horse to electric traction. He then became manager of the British Schukert Electric Co., Ltd., London, in charge of the Central Station Dept. of the Siemens Brothers Dynamo Works, Ltd., at London. In 1908, he became interested in the management of the British Aluminium Co., Ltd., with whom he was affiliated at the time of his death. His work with them was the development of the use of aluminum for general industrial purposes, with particular attention to its application for electrical purposes. Mr. Jacob was a member of the Overhead Wires Committee

of the British Engineering Standards Association, the Overhead Wires Committee of the British Electrical Research Association, the Institution of Electrical Engineers, the American Electrochemical Society, the Institute of Metals, and was also identified with the work of the British Engineers' Association, the Federation of British Industries, the Industrial League and Council and many other organizations. He joined the Institute, as a member, in 1919.

Clifton D. Kennedy, born at Denver, Colorado, July 14, 1889, died at Los Angeles, May 15th, 1925. The resolution by the Los Angeles Section of the Institute, of which Mr. Kennedy was a member, describes Mr. Kennedy as a man of "splendid character and a valued and honored citizen." Completing a technical course in high school in 1902, Mr. Kennedy continued his professional training by a three-months' course in business college, from which he was graduated in 1904. He then attended the South Carolina Military Academy for two years and graduated from the Naval Engineering School in 1910. He also took a course at Drexel Institute, finishing there in 1916. Mr. Kennedy's practical experience was of conspicuous worth. He was with the Southern Electric Co. in varying capacities; in 1911, acting chief of the U. S. N. from which he received honorable discharge in 1912, immediately prior to going with the Cramp Shipbuilding Co. (under Mr. G. A. Pierce). In 1915, he was foreman of the Philadelphia Navy Yard and in 1916 served the Walker & Kepler Electric Co. and the United Construction Co. in like capacity. In 1917, he was made power man for the Western Electric leaving that position to become Assistant Foreman for the Edwin G. Budd Mfg. Co. He was a year with the Midvale Steel Works, the Reading Railroad and the Westinghouse Mfg. Co. From 1921 to 1923, Mr. Kennedy taught school. He was also author of 72 published lectures on a-c. equipment. The largest installation ever undertaken by him was a two million dollar operation which he accomplished with a working force of one hundred men over whom he had sole supervision. He joined the Institute in 1923. At the time of his death he was Chief Instructor and Electrical Director of the National Auto & Electrical School, Los Angeles, Calif.

Past Section and Branch Meetings

SECTION MEETINGS

Akron

Transmission of Pictures by Wire, by A. B. Clark, American Telephone & Telegraph Co. Illustrated. May 1. Attendance 85.

Atlanta

Business Meeting. April 24. Attendance 15.

Baltimore

Railways Transportation, by W. B. Potter, General Electric Co. The speaker, with the aid of pictures, discussed the various engineering features involved in modern transportation, showing the comparison of steam and electric propulsion as applied. The modern gasoline engine, the deisel and semi-fuel oil engines were also discussed. A dinner preceded the meeting. January 15. Attendance 96.

The Klydonograph, by Dr. J. F. Peters, Westinghouse Electric & Manufacturing Co. One of the points brought out was the ability of this instrument to measure the velocity of electricity. A dinner preceded the meeting. February 20. Attendance 104.

Design of Power Transformers, by H. O. Stevens, General Electric Company. Refreshments were served. March 20. Attendance 59.

Boston

The Work of the United States Budget Bureau, by Brigadier-General H. M. Lord. April 29. Attendance 114.

Cincinnati

Fault Location in Electric Cables, by Garland Stamper. The talk covered also the development of apparatus for use in this work. April 9. Attendance 30.

Columbus

The Gyroscope and Gyrocompass, by R. B. Lea, Sperry Gyroscope Co. March 27. Attendance 54.

Connecticut

Binaural Radio Broadcasting and Reception, by F. M. Doolittle, Doolittle Radio Corp. April 15. Attendance 70.

The Magnetic Determination of the Structural Characteristics of Steel, by Frank P. Fahy. Refreshments were served. April 20. Attendance 25.

Denver

Engineering Experiences in Japan, by P. C. Van Zandt, Ideal Cement Co. April 17. Attendance 18.

Detroit-Ann Arbor

Carrier-Current Systems, by A. F. Rose, American Telephone and Telegraph Co. With the aid of a motion picture, entitled "The Audion," and lantern slides, the speaker explained the theory of carrier-current systems. April 21. Attendance 150.

Erie

Electric Welding, by James Burke, Burke Electric Co. April 21. Attendance 200.

Fort Wayne

Financial Problems of Public Utilities, by Mr. Bohn, Home Telephone and Telegraph Co. An inspection trip was made through the new building of the company where the new automatic exchange was explained.

Ithaca

Railway Electrification in Europe, by O. K. Marti, Cornell University. April 15. Attendance 250.

Some Problems in Long-Distance Transmission, by R. E. Doherty, General Electric Co. May 1. Attendance 55.

Vital Factors in Engineering Progress and Education, by L. T. Robinson, General Electric Co. Annual Banquet. May 11. Attendance 125.

Lehigh Valley

Power Factor, by H. S. Bowman, Philadelphia Electric Co.

Telephone Consolidation, by E. M. Prisk, Lehigh Telephone Co., and

Automatic Substation of the Hazelton and Wilkes-Barre Railway, by Eckley Markle. Dinner preceded the meeting. April 24. Attendance 220.

Los Angeles

In the Dark, by R. Lee Heath, Chief of the Los Angeles Police Department. The talk dealt with the advantages of good street illumination.

Street Lighting, by O. W. Holden, Bureau of Power and Light, Los Angeles. Illustrated by slides. A dinner preceded the meeting. April 14. Attendance 119.

Lynn

Inspection trip to the Edison Electric Illuminating Company of Boston. December 6. Attendance 130.

Various Types of Bearings, by E. G. Gilson, General Electric Research Laboratory. A talk was also given by E. S. Candor, Texas Oil Co., who explained the processes through which crude oil has to pass in refining and distilling plants. He further explained the various qualities and the purposes for which they were best suited. January 20. Attendance 27.

Direct-Current Watthour Meters, by H. G. Hamann, F. P. Church and H. M. Witherow, all of General Electric Co., and

The Problems of Remote Indication and Recording and Indicating Total Station Load, by H. K. Nock, General Electric Co. February 4. Attendance 103.

The Navy, Its Ships and Men, by Commander J. S. Evans, U. S. Navy. A motion picture showing the activities on board ship was shown. Refreshments were served. February 11. Attendance 276.

Inspection trip to the New England Telephone and Telegraph Company. A talk was given by the officers of the company on the history of the development of the telephone from the old magneto-call type to the present system of automatic machine-operated stations. February 14. Attendance 97.

Crystal Structure, by W. P. Davey, General Electric Research Laboratory. Illustrated with slides. February 17. Attendance 206.

Our National Parks, by H. W. Gleason. March 3. Attendance 375.

Inspection trip to the manufacturing plant of the Paine Furniture Company. March 14. Attendance 15.

Lightning, by F. W. Peek, Jr., General Electric Co. Illustrated by photographs and moving pictures. Joint meeting with the Thompson Club. March 18. Attendance 222.

Diamonds and the Diamond Mines of South Africa, by Dr. Charles Palache. Samples of many diamonds and the rock formation in which they are found, were on exhibition. March 19. Attendance 233.

A Symposium on the Origin of Life, by Dr. Harlow Shapley, Dr. G. H. Parker and Dr. Kersopp Lake, and

A talk by Dr. Farley Osgood, National President, A. I. E. E. Dr. Osgood spoke on the activities of the National Body and the many services available to members. A short talk was also given by Vice-President H. B. Smith. Annual Dinner. March 28. Attendance 425.

Milwaukee

The University and Industry, by W. O. Hotchkiss. A number of the members of the faculty of the University of Wisconsin attended the meeting and gave a description of research work which was being carried on at the University. April 15. Attendance 150.

Minnesota

Heavy Alternating-Current Distribution, by S. B. Hood, Northern States Power Company. March 23. Attendance 55.

Carrier-Current Telephone Systems as Applied to Power-Transmission Lines, by G. H. Williams, Westinghouse Electric & Mfg. Co. Illustrated by slides. April 27. Attendance 59.

Niagara Frontier

Electrical Development in Japan, by S. Q. Hayes, Westinghouse Electric & Mfg. Co. An inspection trip to the No. 3 Power House at Niagara Falls was made. April 30. Attendance 57.

Oklahoma

Specific Head, Specific Gravity and Temperature Relations of Petroleum Oils, by Prof. W. R. Eckart, Leland-Stanford University. Illustrated. Joint meeting with A. A. E., A. C. S., A. I. M. M. E., A. P. I., A. S. C. E., A. S. M. E., N. A. S. E., N. S. C. and Oklahoma Technical Club. Dinner was served. April 24. Attendance 43.

Philadelphia

What A College Man Goes Up Against and How to Meet It, by Farley Osgood, President, A. I. E. E. Entertainment was furnished by members of the University of Pennsylvania Student Branch. March 9. Attendance 320.

Manual and Automatic Control of Induction and Synchronous Motors, by H. D. James. Westinghouse Electric & Mfg. Co. April 17. Attendance 155.

Pittsburgh

Lightning and Other Forms of Natural Electricity, by John B. Taylor, General Electric Co. The speaker discussed the various methods by which electricity can be produced artificially. April 14. Attendance 120.

Portland

Disturbances Due to 11-Kv. Lines, by L. H. Kistler, Western Electric Co. Illustrated.

Interfering Effects Due to Small Electrical Devices, by W. R. Cornell, Portland Electric Power Company. Illustrated with demonstrations with X-ray tubes, toy motors, thermostats, and Violet-ray outfits.

The Future of Radio, by Jos. H. Hallock, Hallock and Watson, Radio Service. Refreshments were served. April 8. Attendance 200.

Providence

The Pulse of the World, by P. J. Macken, Postal Telegraph Company. April 7. Attendance 100.

The Electrical Industry and Its Future, by R. M. Davis, *Electrical World*. Joint meeting with Power Section of Providence Engineering Society. April 15. Attendance 30. Three films, entitled "The Development of Power," were shown. Pictures of large modern steam and water-power plants, including the new Weymouth Station and the Big Creek Water Power Development were also shown. The following officers were elected: Chairman, William P. Field; Vice-Chairman, Edwin E. Nelson; Secretary-Treasurer, Frederick N. Tompkins; Executive Committee, W. W. Broadbent and E. S. Esty. May 8. Attendance 35.

Rochester

Motion pictures were shown. Business Meeting. April 17. Attendance 45.

Seattle

Broadcasting by Radio and Long Lines, by J. R. Tolmie and J. W. Greig, both of Pacific Telephone & Telegraph Co. March 18. Attendance 61.

Springfield

Arc Welding, by R. E. Wagner, General Electric Co. Illustrated with slides and moving pictures, together with an exhibit of different kinds of metal. April 27. Attendance 44.

St. Louis

An illustrated talk was given by G. H. Pring, horticulturist of Shaw's Garden, on his experiences while collecting orchids in South America. January 28. Attendance 150.

Achievements in Electrical Engineering, by Walter Bryan, B. F. McNamee, G. H. Duerman and C. C. Robinson. February 25. Attendance 85.

Electrical Transmission of Pictures, by R. D. Parker, American Telephone & Telegraph Co. Parts of the apparatus and many specimens of pictures transmitted were exhibited. March 25. Attendance 205.

Syracuse

The New Weymouth Power Plant of the Boston Edison Company, by Albert Northrup, Stone and Webster. Illustrated by film, entitled "Power." March 23. Attendance 110.

The Air Mail, by L. K. Bell. Illustrated by motion pictures. April 20. Attendance 136.

Toledo

Inspection trip to the Ford Plate Glass Company. April 17. Attendance 60.

Toronto

An oscillograph demonstration of some voltage and current wave forms was given by H. W. Price, General Electric Co. The speaker ended his demonstration by a description of a two speed synchronous motor being developed by the General Electric Co. Mr. P. A. Borden described some of his experiences with the oscillograph. April 17. Attendance 114.

A talk was given by Dr. J. Slepian, Westinghouse Electric & Mfg. Co., in which he described the formation of clouds, the charging of air particles and the conditions which caused lightning. Refreshments were served. April 24. Attendance 235.

An interesting travelogue on Australia and New Zealand was given by Professor Coleman. The following officers were elected: Chairman, L. B. Chubbuck; Secretary, W. L. Amos; Executive Committee, C. E. Sisson; M. B. Hastings, M. J. McHenry, A. R. Zimmer, F. F. Ambuhl and E. M. Wood. May 1. Attendance 120.

Urbana

Business Meeting. The following officers were elected: Chairman, Charles A. Keener; Secretary, Joseph T. Tykociner. May 6. Attendance 15.

Vancouver

Design of Metal-Clad Switchgear, by H. W. Clothier, A. Reyolle & Co., Ltd. Illustrated by slides. May 1. Attendance 33.

Washington, D. C.

Some Economic Principles Applied to Lighting Practise, by George H. Stickney, the Edison Lamp Works. April 14. Attendance 51.

Worcester

Railroad Electrification, by J. Van Buren Duer, Pennsylvania Railroad. April 30. Attendance 50.

BRANCH MEETINGS

University of Arkansas

A motion picture on student test work with the General Electric Company was shown. April 7. Attendance 22.

Armour Institute of Technology

Mr. C. H. Jones, Electrical Engineer for the North Shore and Milwaukee Railroad and for the Chicago Surface and

Elevated Lines, outlined some of the problems in connection with the North Shore Line. March 19. Attendance 28.

Fused Quartz, by R. E. Devin, General Electric Co. Illustrated by slides. The small index of refraction of quartz was demonstrated together with other experiments. April 16. Attendance 55.

Brooklyn Polytechnic Institute

Business Meeting. Professor R. S. Beach told of the value of the student paper in developing the future engineers. The prize of ten dollars was presented to Sanford Farkas for the student paper of the year. The following officers were elected: President, John C. Arnell; Treasurer, James J. McMullan; Vice-President, William R. Berger; Secretary, John H. Diercks. May 13.

California Institute of Technology

Recent Developments in Electric Meters, by Mr. Grimes, Westinghouse Electric & Mfg. Co. The speaker showed samples of Westinghouse meters. April 30. Attendance 12.

Carnegie Institute of Technology

Power Developments in Japan, by S. Q. Hayes, Westinghouse Electric & Mfg. Co. Motion pictures were shown. April 28. Attendance 27.

Clarkson College of Technology

Porcelain Insulators, by F. H. Porter. Illustrated lecture. March 13. Attendance 15.

Inspection trip to the hydroelectric plants of the St. Lawrence Utilities Company. April 29. Attendance 45.

University of Denver

Mr. Fred Berger gave an interesting description of the million-volt cascade transformer developed by the California Institute of Technology. April 17. Attendance 18.

White Coal, by C. G. Diller,

Principles of the Induction Motor Experimentally Demonstrated by F. R. Schmidt,

Arc-Welding Transformers, by Stuart G. Ellis,

The Magnetic Ore Separator, by Robert R. McLaughlin, and

Demonstrations with High Frequency and High Voltages, by Rupert E. Kelso and T. R. Cuykendall. Refreshments were served. April 23. Attendance 54.

Kansas State College

The Electron Theory, by Professor Rayburn. April 26. Attendance 68.

University of Kansas

Brush Troubles and Carbon Brushes, by J. A. Robinson, National Carbon Company. April 23. Attendance 51.

Lehigh University

Telephone Engineering as a Profession, by O. W. Eshbach, Bell Telephone Company of Pa., and

The History of Bakelite, by F. J. Berger, student. Refreshments were served. April 30. Attendance 75.

Marquette University

Inspection trip to the Line Materials Company at S. Milwaukee. Mr. A. Steinmayer spoke on the Manufacture of Porcelain. A number of demonstration tests were made on the 100,000-volt transformer. April 30. Attendance 34.

Massachusetts Institute of Technology

Advance of the Electrical Industry with Particular Reference to Electric Light and Power, by R. M. Davis, *Electrical World*. Illustrated with slides. April 17. Attendance 15.

Michigan State College

The Necessity of Taking Part in Civil Affairs, by J. Converse, Assistant Attorney General. April 28. Attendance 28.

University of Michigan

Inspection trip to the Detroit Edison Company. The party was shown an automatic control installation. May 1. Attendance 11.

The History of Power Development at Niagara Falls from the Days of the Pioneer to the Present, by W. K. Bradbury, Niagara Falls Power Company. Illustrated with slides. May 4. Attendance 126.

Inspection trips to the Michigan Bell Telephone Company, where automatic machine-switching devices were in operation. The party then continued to the Detroit Edison Company. May 5. Attendance 52.

Missouri School of Mines and Metallurgy

Practical Radio Reception, by Professor F. H. Frame. April 10. Attendance 11.

Social Meeting. April 24. Attendance 10.

University of Nevada

Business Meeting. The following officers were elected: Chairman, Lloyd Crosby; Secretary-Treasurer, Mr. Samuels. April 22. Attendance 15.

College of the City of New York

Business Meeting. April 23. Attendance 13.

Business Meeting. April 30. Attendance 10.

Inspection trip to Mazda Lamp Works of the General Electric Co. Talks accompanied by practical demonstrations were given on industrial, street, and home lighting. April 28. Attendance 15.

The Business Methods of a Large Electrical Manufacturer, by Professor Harry Baum. May 14. Attendance 19.

University of North Carolina

Business Meeting. April 30. Attendance 18.

Northeastern University

The Electrical Industry and Its Future, by R. M. Davis, *Electrical World*. April 11. Attendance 52.

Inspection trip through the Weymouth Plant of the Boston Edison Electric Illuminating Company. April 24. Attendance 32.

Ohio Northern University

Principles of Mercury-Arc Rectifier, by R. J. Anspach,
Initial Cost of an Electric Railway, by P. Funk, and
Development of Niagara Falls Hydraulic Power, by J. Ring. The following officers were elected: Chairman, H. N. Leslar; Vice-Chairman, C. R. Grace; Secretary, F. Boulton; Treasurer, M. Lee. April 23. Attendance 20.

Oklahoma Agricultural and Mechanical College

The Use of Electricity in the Oil Fields, by C. E. Middleton, General Electric Co. Joint meeting with A. S. M. E. April 29. Attendance 30.

Oklahoma University

Motion pictures were shown. April 7. Attendance 20.

Pennsylvania State College

Substation and Switching Apparatus, by Professor Forbes. Illustrated. March 30. Attendance 68.

Rhode Island State College

Life of Michael Pupin, by S. J. Bragg. March 18. Attendance 16.

The 220,000-Volt Transmission Lines in California, by W. F. Lucker. April 1. Attendance 12.

Motion pictures, entitled respectively "Speeding the Spoken Word" and "The Transmission of Intelligence." April 15. Attendance 18.

Inspection trip to General Electric Works at Lynn. April 22.

Automatic Voltage-Control Systems, by J. A. Christensen. April 29. Attendance 10.

Rutgers University

The Application of Electricity to the Cotton Industry, by Mr. Coleman. April 22. Attendance 13.

University of Southern California

Inspection trip to the Southern California Telephone Company's University Office. March 12. Attendance 30.

Steam Turbines, by Mr. Hamilton, Westinghouse Electric & Mfg. Co. Illustrated. March 19. Attendance 30.

South Dakota State School of Mines

The Need of Engineers in Large Industries, by P. M. McCullough, Northwestern Bell Telephone Co. A short talk was also given by O. W. Johnson of the same company. Refreshments were served. April 29. Attendance 26.

University of South Dakota

Lecture by Dr. Daines, University of Kansas. April 30. Attendance 27.

Stanford University

Business Meeting. April 7. Attendance 11.

Business Meeting. New constitution adopted. April 14. Attendance 21.

The Manufacture and Use of Transformers, by F. Smith, General Electric Co. Illustrated by slides and models. May 6. Attendance 27.

University of Utah

Harmonics, by Ira Terry, student. April 22. Attendance 13.

Virginia Military Institute

A New Type of Induction Motor, by J. L. White,
The Brooklyn Edison Company, by F. G. Lake, and
Opportunities in Illumination, by R. F. Hill. April 26. Attendance 44.

Virginia Polytechnic Institute

Alternating-Current Generators and Synchronous Motors, by K. E. Whitney, General Electric Co. April 29. Attendance 36.

University of Virginia

Queenstown-Chippewa Development, by J. E. Glick. Illustrated. A General Electric film was also shown. May 5. Attendance 25.

University of Washington

The Modern Receiver, by T. M. Libby. April 7. Attendance 32.

West Virginia University

The Successful Engineer, by H. O. Cole, Cole Brothers Construction Company. Short talks were given by Dr. A. H. Forman, Prof. A. A. Hall, L. F. Warden, R. W. Beardsley and Dean C. R. Jones. Annual Banquet. April 29.

The National Tube Mill, by Mr. Wolfe,
Hudson Avenue Station of the Brooklyn Edison Company, by Mr. Devebre,
Continuous Utility Advertising by the Pacific Gas & Electric Company, by Mr. Smith,
A Turbine Locomotive, by Mr. Roush,
The Virginia Locomotives, by Mr. Worden, and
The Coil-Winding Department of Westinghouse Electric and Manufacturing Company, by Mr. Crush. April 30. Attendance 25.
The Jones and Laughlin Steel Mill, by Mr. Reynolds,
The American Steel and Wire Company, by Mr. Addis,
The Kelvinator, by Mr. Cole,
The Springdale Power Plant of the West Penn Power Company, by Mr. Holmes, and
Magnetic Properties of Magnetic Materials, by Mr. Meintell. May 8. Attendance 25.

University of Wisconsin

Railway Electrification in the United States, by Professor J. T. Rood. The following officers were elected: Chairman, Norman G. Robisch; Secretary-Treasurer, Stanley Roland. April 22. Attendance 21.

Engineering Societies Library

The library is a cooperative activity of the American Institute of Electrical Engineers, the American Society of Civil Engineers, the American Institute of Mining and Metallurgical Engineers and the American Society of Mechanical Engineers. It is administered for these Founder Societies by the United Engineering Society, as a public reference library of engineering and the allied sciences. It contains 150,000 volumes and pamphlets and receives currently most of the important periodicals in its field. It is housed in the Engineering Societies Building, 29 West Thirty-ninth St., New York.

In order to place the resources of the Library at the disposal of those unable to visit it in person, the Library is prepared to furnish lists of references to engineering subjects, copies or translations of articles, and similar assistance. Charges sufficient to cover the cost of this work are made.

The Library maintains a collection of modern technical books which may be rented by members residing in North America. A rental of five cents a day, plus transportation, is charged.

The Director of the Library will gladly give information concerning charges for the various kinds of service to those interested. In asking for information, letters should be made as definite as possible, so that the investigator may understand clearly what is desired.

The library is open from 9 a. m. to 10 p m. on all week days except holidays throughout the year except during July and August when the hours are 9 a. m. to 5 p. m.

BOOK NOTICES MAY, 1924

Unless otherwise specified, books in this list have been presented by the publishers. The society does not assume responsibility for any statements made; these are taken from the preface or the text of the book.

All the books listed may be consulted in the Engineering Societies Library.

TRANSMISSION CIRCUITS FOR TELEPHONIC COMMUNICATION.

By K. S. Johnson N. Y., D. Van Nostrand Co., 1925. 326 pp., diagrs., 9 x 6 in., cloth. $5.00.

This book covers the general theory and principles which are applicable to the development and design of circuits and lines to be associated with such telephonic instruments as transmitters, receivers and vacuum tubes. The book is based on the work of the author and his colleagues in the Bell Telephone Laboratories, and is the outgrowth of his course of instruction to the members of its technical staff on the analytical study of telephonic transmission.

INTERNAL-COMBUSTION ENGINES.

By Wallace L. Lind. 2d. edition, revised. Annapolis, Md., U. S. Naval Institute, 1925. 266 pp., illus., diagrs., 9 x 6 in., cloth. $3.00.

The author has aimed to provide a practical, up to date text, suited to the comprehension of the average student and planned for those who will operate such engines rather than design them. The new edition has been thoroughly revised by the elimination of obsolete matter and the addition of new matter pertaining to aircraft, Diesel and the Navy Type V engines. The work is apparently intended primarily for use in the United States Naval Academy.

TESTING OF HIGH SPEED INTERNAL COMBUSTION ENGINES.

By Arthur W. Judge. N. Y., D. Van Nostrand Co., 1925. 392 pp., illus., diagrs., tables, 9 x 6 in., cloth. $7.50

As a companion to his previous works on internal combustion engines, Mr. Judge has now issued this work on the methods of testing these engines and the apparatus used in testing. He has tried to present the subject in a practical way, neither too elementary nor too advanced for the ordinary needs of engineers and manufacturers, while the needs of those engaged in advanced work and research are met by references to original papers and by bibliographies.

TELEPHONE COMMUNICATION.

By Charles Allen Wright and Albert F. Puchstein. N. Y., McGraw-Hill Book Co., 1925. 515 pp., diagrs., 9 x 6 in., cloth. $5.00.

In order to limit the size of this work, only the problems connected with alternating currents of medium frequency are emphasized, and those related to direct currents and currents of low and high frequencies are discussed only enough to show their relation to telephone communication. The book therefore, dealing as it does with currents of audio frequency, is a study of those parts of telephone talking circuits which generate, transform, transmit and detect voice currents and electro-motive forces. It deals largely with the conditions that cause attenuation or distortion and with means for decreasing them.

Rapports et Discussions sur Cinq Questions D'Actualite.

Premier Conweil de Chimie tenu a Bruxelles, Avril, 1922, sous les auspices de L'Institut International de Chimie Solvay.

Paris, Guathier-Villars et Cie., 1925. 336 pp., illus., 10 x 6 in., paper. 30 fr.

The reports presented to the Council, summarizing present knowledge of five fundamental problems of chemistry, were: Isotopy and radioactivity, by Frederick Soddy; Molecular structure and X-Rays, by Sir W. H., Bragg; Molecular structure and optical activity, by Sir William Pope; Valency, by Charles Mauguin; and Chemical mobility, by André Job. These reports, together with the discussion of them by the twenty-five prominent chemists who composed this first Council, form the present volume.

The Chemical Councils, founded by Ernest Solvay, are intended to bring together, from time to time, selected groups of chemists from various countries, for the discussion of important questions.

Non-Metallic Minerals; Occurence, Preparation, Utilization.

By Raymond B. Ladoo. N. Y., McGraw-Hill Book Co., 1925. 686 pp., 9 x 6 in., cloth. $6.00.

A very thorough compilation of the data available on the technology of the non-metallic minerals of commercial importance. The information includes the composition and properties of the minerals, methods of mining and preparation, market values, extent and nature of markets, specifications and uses. The book is the first to attempt so extensive a survey of this subject. Bibliographical references accompany each chapter.

Molybdenum, Cerium and Related Alloy Steels.

By H. W. Gillett and E. L. Mack. N. Y., Chemical Catalog Co., 1925. (American Chemical Society. Monograph series.) 299 pp., illus., diagrs., tables, 9 x 6 in., cloth. $4.00.

As the United States has large reserve supplies of molybdenum, while the domestic supply of the other metals that are important in making alloy steels is small, the desirability of developing the molybdenum steels is of obvious importance to American steel makers and users. This book reviews and extends our knowledge of the possibilities and limitations of molybdenum as an alloying element and presents a record of new investigations of its effect on endurance and impact properties and on the properties of "transverse" specimens. An extensive bibliography is given.

Metallurgy of Aluminium and Aluminium Alloys.

By Robert J. Anderson. N. Y., Henry Carey Baird & Co., 1925. 913 pp., illus., diagrs., tables, 9 x 6 in., cloth. $10.00.

Since the last revision of Richards' classic work in 1896 no book has been published dealing with the metallurgy of aluminum and its alloys, and there is evident need for a modern work on this important metal. Mr. Anderson treats the subject from the point of view of the metallurgical engineer concerned with the production of the metal and its alloys in raw or manufactured form and endeavors to avoid both the academic and the over practical viewpoint. The book is comprehensive in its scope, covering the production of aluminium and aluminium alloys, their physical and chemical properties, methods of working, heat treatment, uses, etc. Good bibliographies are given.

Linienfuhrung.

By Erich Giese. Otto Blum & Kurt Risch. Berlin, Julius Springer, 1925. (Handbibliothek für Bauingenieure, t. 2, bd. 2.) 435 pp., illus., diagrs., 10 x 7 in., boards. 21,-g. m.

A comprehensive work on railroad location and construction, in which both economic and engineering problems are considered. The book is intended as a text-book and also for use for reference.

Laboratory Manual of Experiments in Physics.

By Leonard Rose Ingersoll. N. Y., McGraw-Hill Book Co., 1925. 220 pp., diagrs., tables, 8 x 6 in., cloth. $2.00.

This manual, prepared primarily for students at the University of Wisconsin, contains a graduated series of experiments on mechanics, heat, electricity, magnetism, wave motion, sound and light, which vary from those suited to students without previous training to experiments suited to sophomores.

Henley's Twentieth Century Formulas, Recipes and Processes.

Edited by Gardner D. Hiscox. N. Y., Norman W. Henley Publishing Co., 1924. 807 pp., 9 x 6 in., cloth. $4.00.

It having become necessary to reprint this popular work, the occasion has been seized to include a new chapter on general methods for compounding recipes. The book contains several thousand recipes and processes for substances used in the workshop and the household.

Field Engineering.

By William H. Searles. 19th edition, rev. & enl. by H. C. Ives. N. Y., John Wiley & Sons, 1925. 2v. in 1, diagrs., tables, 7 x 4 in., fabrikoid. $4.00.

This pocket-book, which has been in use for forty-five years and has gone through many editions, is too well known to need description. The nineteenth edition has been so extensively revised as to necessitate a resetting of the entire text. Certain portions have been rearranged, some sections have been omitted and much new material has been added. The book still remains, however, small enough to be carried conveniently in the pocket, even when the two volumes are bound together.

Das Fernsprechwesen, v. 1; Grundlagen und Einzelapparate der Fernsprechtechnik.

By W. Winkelmann. Ber. u. Lpz., Walter de Gruyter & Co., 1925. 123 pp., illus., diagrs., tables, 6 x 4 in., cloth. 1,25 gm.

A revised edition of the first half of a concise yet comprehensive textbook on telephony. The present volume discusses telephone transmitters and receivers and their parts, switches, conductors, safety devices, etc. The second volume will treat of central stations.

Elektrochemie........v. 2, Experimentelle Elektrochemie.

By Heinrich Dannell. 3rd edition. Ber. u. Lpz., Walter de Gruyter & Co., 1925, 131 pp., diagrs., tables, 6 x 4 in., cloth. 1,25 mk

Describes the theory, construction and use of electrochemical meters for measuring voltage, amperage, resistance, conductivity, concentration of ions, etc. Discusses questions of conductivity and the electrochemistry of solutions. The book is an excellent brief account of modern conceptions, suited especially for ready reference.

Elektrische Gleichrichter und Ventile.

By A. Günther-Schul e. München, Josef Kösel & Friedrich Pustet, 1924. 181 pp., diagrs., 8 x 5 in., boards. 6,20 gm.

A condensed account of the properties and uses of the vacuum tube as a rectifier of current, a source of high-frequency current, etc. The subject is treated in a severly practical manner and the information is confined to modern ideas and methods. A considerable bibliography is given.

Electricity Meter Practise.

By H. G. Solomon. Lond., Charles Griffin & Co.; Phila., J. B. Lippincott Co., 1923. 189 pp., diagrs., tables, 8 x 5 in., cloth. 7s 6d.

A general, elementary book on theory and practise, based on the author's larger work, "Electricity Meters." It gives a simple representation of the principles of operation and the behavior and testing of current meters, with special reference to the service and recalibration of those of the motor type.

Bituminous Substances.

By Percy Edwin Spielmann. Lond., Ernest Benn, Ltd., 1925. 206 pp., illus., diagrs., tables, 9 x 6 in., cloth. 15 s.

Dr. Spielmann has collated the useful information that has appeared in print during the past fifteen years, with the object of bringing together what is known of the chemistry of bitumens and of correlating, as far as possible, their chemical composition with their physical behavior and properties. His book discusses the composition, origin and properties of the bitumens, the effects of heat, aging and solvents, and the physical and chemical tests in vogue. A good bibliography is included.

Automotive Electricity.

By Earl L. Consoliver. N. Y., McGraw-Hill Book Co., 1925. 665 pp., illus., diagrs., 9 x 6 in., cloth. $4.00.

A textbook for workmen who wish to engage in the maintenance and repair of electrical equipment, arranged for home study. Covers, the author states, all the makes and types of electrical and battery systems used on automobiles, aircraft, motor boats and stationary engines.

Acid-Resisting Metals.

By Sydney J. Tungay. 136 pp., diagrs., tables.

Agitating, Stirring and Kneading Machinery.

By Hartland Seymour. 139 pp., illus., diagrs., tables.

Mechanical Mixing Machinery.

By Leonard Carpenter. 138 pp., illus. Lond., Ernest Benn, Ltd., 1925. (Chemical Engineering Library. 2d series.) 8 x 5 in., cloth. 6s each.

These three small volumes of the "Chemical Engineering

Library" deal with matters of importance to every branch of chemical industry but which have usually received little special attention in previous books. They make no pretence to be comprehensive, but they provide an outline of the principles involved and a description of some successful methods for accomplishing the desired results. The viewpoint is that of the chemical engineer rather than that of the mechanical engineer and metallurgist.

Addresses Wanted

A list of names of members whose mail has been returned by the postal authorities is given below, together with the addresses as they now appear on the Institute records. Any member knowing the present address of any of these members is requested to communicate with the Secretary at 33 West 39th St., New York, N. Y.

All members are urged to notify the Institute headquarters promptly of any change in mailing or business address, thus relieving the member of needless annoyance and also assuring the prompt delivery of Institute mail, the accuracy of our mailing records, and the elimination of unnecessary expense for postage and clerical work.

1.—E. T. Benderoth, 834 Golden Ave., Baryman Apt., Los Angeles, Calif.
2.—Clyde E. Bentley, 2815 Kelsey St., Berkeley, Calif.
3.—G. De La Rochette, c/o Westinghouse Elec. Int'l Co., 2 Norfolk Strand, London W. C. 2, England.
4.—William J. Gough, Box 230, Sea Cliff, L. I., N. Y.
5.—Harry A. Gould, So. Calif. Edison Co., 1201 W. 2nd St., Engg. Dept., Los Angeles, Calif.
6.—Thomas L. Henritze, P. O. Box 27, Pikeville, Ky.
7.—Edwin P. Hill, c/o Radio Corp. of America, Bolinas, Calif.
8.—William B. Hoey, High Tension Supplies Co., Wilmington, Del.
9.—F. M. Kenney, 611 North Lime St., Lancaster, Pa.
10.—W. L. McGeehan, The Ohio Power Co., Philo, Ohio.
11.—H. J. Mitchell, 42 Second Street, Elmhurst, L. I., N. Y.
12.—I. B. Watkins, 124 East Symmes St., Norman, Okla.

Engineering Societies Employment Service

Under joint management of the national societies of Civil, Mining, Mechanical and Electrical Engineers as a cooperative bureau available only to their membership, and maintained by contributions from the societies and their individual members who are directly benefited.

MEN AVAILABLE.—Brief announcements will be published without charge and will not be repeated, except upon requests received after an interval of one month. Names and records will remain in the active files of the bureau for a period of three months and are renewable upon request. Notices for this Department should be addressed to ***EMPLOYMENT SERVICE, 33 West 39th Street, New York City,*** *and should be received prior to the 15th of the month.*

OPPORTUNITIES.—A Bulletin of engineering positions available is published weekly and is available to members of the Societies concerned at a subscription rate of $3 per quarter, or $10 per annum, payable in advance. Positions not filled promptly as a result of publication in the Bulletin may be announced herein, as formerly.

VOLUNTARY CONTRIBUTIONS.—Members obtaining positions through the medium of this service are invited to cooperate with the Societies in the financing of the work by nominal contributions made within thirty days after placement, on the basis of $10 for all positions paying a salary of $2000 or less per annum; $10 plus one per cent of all amounts in excess of $2000 per annum; temporary positions (of one month or less) three per cent of total salary received. The income contributed by the members, together with the finances appropriated by the four societies named above, will it is hoped, be sufficient not only to maintain, but to increase and extend the service.

REPLIES TO ANNOUNCEMENTS.—Replies to announcements published herein or in the Bulletin, should be addressed to the key number indicated in each case and with a two cent stamp attached for reforwarding, and forwarded to the Employment Service as above. Replies received by the bureau after the positions to which they refer have been filled will not be forwarded.

POSITIONS OPEN

ENGINEER, familiar with the design of electrical apparatus needed in connection with control and regulation of oil burning apparatus. Location, East. R-6326.

INSTRUCTOR, in electrical engineering, with at least two years' practical experience. Salary $2000-$2200 a year. Start work September 1925. Location, Arizona. R-6308.

ELECTRICAL ENGINEER, experienced in developing small electrical machines and devices. Knowledge of spot welding and heat resistance units desirable. In reply cite some problem solved that was extraordinary stating how it was accomplished. Also cover general experience, age, education and starting salary expected. Location, Middlewest. R-5962.

INSTRUCTOR, electrical engineer, to teach electrical machinery for mechanical engineers, and elementary design for electrical engineers. Practical experience of two or more years essential; teaching experience not required, but desirable; engineering school graduate preferred, but applicants who have had a shorter training course will be considered. Salary $1800-$2000 for school year of nine months beginning September 1925. Apply by letter stating experience, education, religious affiliation and send photograph. Location, New York. R-6335.

MEN AVAILABLE

FIELD ENGINEER, age 28, married, graduate electrical engineer 1920, one year G. E. Test, two years power plant operation and construction, two years construction of transmission and distribution substations. Desires similar position with consulting engineer or public utility. Would consider position in power sales or sales engineering. B-6010.

TEACHER electrical engineering, desires professorship; ten years of teaching experience covers all of the usual electrical engineering courses. Well acquainted with the industry through design, application and construction experience. Available in September. B-7083.

MECHANICAL AND ELECTRICAL DESIGN AND CONSTRUCTION ENGINEER, technical graduate, age 30, single, four years' shop experience various machines, five and one-half years employed by Brown, Boveri Company, Switzerland, designer of pumps, electric furnaces, transformers, cranes and structural steel works. Two years construction designer of A-C. and D-C. machines by the Canadian Crocker-Wheeler Company. Speaks German, French and English. B-9708.

YOUNG MAN, age 27, B. S. in E. E., wishes position with consulting engineer or contractor, not necessarily in electrical work. Has had four years telephone experience in maintenance and outside plant engineering and some railway maintenance engineering. Prefer Middle Western location. B-9769.

ASSISTANT ELECTRICAL ENGINEER, age 32, married, technical education and ten years' experience in power plant and substation construction and operation. Salary $3000. Available thirty days' notice. B-9768.

ELECTRICAL ENGINEER, technical education, English, age 28, single, desires post, preferably in Northern States or Canada. Experience covers five years on design, operation and maintenance with power companies in England and Cuba, also three years as inspector with consulting engineer. Knowledge of Spanish and German. Available at once. B-9761.

GRADUATE ELECTRICAL ENGINEER, age 30, married, six years good general experience in design, operation and maintenance of power plants and transmission system. Desires position with public utility or electrical manufacturer with opportunity to specialize. Middlewest or West preferred. Minimum salary $2400. Available on reasonable notice. B-9474.

RECENT ELECTRICAL ENGINEERING GRADUATE, age 23, single, desires position, preferably with an electrical railway, either trunk, interurban, or city lines. Ten months' experience on test course Westinghouse Electric and Manufacturing Company. Prefers application or operating engineering work, or both. Available on reasonable notice. Location, Middlewest or South. B-9757.

PROFESSOR OF ELECTRICAL ENGINEERING seeks change. Available as head of department in progressive institution of moderate size, or as director of engineering laboratory, where broad successful educational experience, sound training, general culture and cooperative spirit are desired. B-2824.

ELECTRICAL ENGINEER, age 29, married, two years university teacher, approximately five

years motor design experience with large electrical corporation. Available on short notice. B-9783.

ELECTRICAL ENGINEER, 39, married, fourteen years' experience, desires change. Past ten years have had entire charge design, installation, maintenance and operation of all kinds of electrical apparatus on large railroad. Make good electrical superintendent for concern with number of plants, such as manufacturer, or oil company. Middlewest or Southwest preferred. B-9772.

DESIGNING ENGINEER, age 37, married, graduated as Ph. D. from university in Germany. Thirteen years' experience as designer of D. C. and A. C. motors with A. E. G. Berlin: expert for induction motors. Desires similar position. B-9792.

ASSISTANT EXECUTIVE, position desired with growing company in commercial or engineering capacity, preferably as assistant to general executive. At present assistant to the chief engineer of machinery manufacturing company. Ten years' experience since graduation, as electrical engineer covering design of machinery and control equipments, manufacture of controllers, appraisal, maintenance and power plant operation. A-280.

ASSISTANT TO GENERAL SUPERINTENDENT of large electrical utility desires change. Sc. B. and E. E. degrees, age 30, married, seven years' experience with general utility problems, cost analysis, budgets, statistics, special engineering reports, organization, secretarial duties, etc. Negotiations relative to a permanent position paying not less than $300 a month invited. B-3311.

TECHNICAL GRADUATE, electrical engineer, single, age 26, desires position with company offering possibilities beyond that of present position. Five years' experience in operation, construction and maintenance of substation and transmission systems. Available thirty days. Location, immaterial. B-6826.

MAINTENANCE ENGINEER, member A. S. M. E. and A. I. E. E., age 38: buildings and equipment, steam and electric power, machine shops and laboratories, efficiency and research, automotive, textile. B-9035.

GRADUATE ELECTRICAL ENGINEER, desires position with public utility or consulting engineer, where organizing and executive, as well as engineering ability is required. G. E. Test, four years' experience with a large public utility and at present employed by consulting engineering firm. Thoroughly familiar with power plant, transmission line and substation work. B-389.

MANUFACTURING EXECUTIVE, age 37, married, electrical engineering graduate, M. S. degree, eleven years' experience in purchasing, factory management and general office experience with some sales work. Seven years in executive capacity in manufacturing companies with sales from one-half to one million dollars. Salary $4000 to $5000. B-9837.

UNIVERSITY GRADUATE, 28, one and one-half years electrical shop construction and maintenance experience, one year with one of largest power distributors at transmission line survey, location, inspection, office drafting. Desires permanent position at transmission line substation, drafting, design. Preferably North Central states or Eastern Canada. $135 per month with opportunity. Available one month. B-9556.

TECHNICAL GRADUATE with experience in electrical work, desires a position as sales engineer with some reputable electrical manufacturing company. Will consider a straight commission proposition. B-6726.

ENGINEER, B. S. in E. E., three years with large electrical manufacturing company, four years teaching engineering subjects in university and other experiences. Desires teaching position in Middlewest or South. B-9850.

GRADUATE ELECTRICAL ENGINEER, 28, American, married, five years drafting and design for power house, substation and transmission line construction with material requisition experience. Desires position preferably New York City, but will go anywhere in United States. B-4217.

ASSISTANT CHIEF ELECTRICAL ENGINEER of large utility corporation desires change. Responsible and capable of taking charge of design, specifications, construction and operation. Graduate E. E., age 38, eighteen years' experience in consulting and utility work. Salary $5000. B-9485.

ELECTRICAL ENGINEER, graduate Cornell University and Westinghouse Apprenticeship Course, married. Ten years' general industrial experience, installation, maintenance, development special electrical features, complicated control apparatus, six years design, production universal motors and their application, two years heavy electric traction, one year industrial sales engineer. Available now. Will go anywhere, but Middlewest and East preferred. Salary $3600. B-9470.

UNIVERSITY GRADUATE, E. E. course, age 30, married, three years electrical, mechanical and sales engineering experience on West Coast, five years telephone engineering and development work in East. Present location New York City; permanent position on Pacific Coast desired. Available for change in location about September 1st. B-9864.

ELECTRICAL ENGINEER, technical graduate, Canadian, married, 32, two years manager branch service station of large electric corporation, two years assistant to plant engineer in manufacturing plant, several months' experience in car barns of electric railway. Desires position with electric railway, or manufacturing concern. Prefers combined engineering and administrative position. Available on reasonable notice. B-9801.

ELECTRICIAN, age 35, married, technical education, sixteen years' experience as trouble shooter, amature winding and station repairs foreman with large public utility company. Desires position of responsibility and chance for advancement, where expert service will be appreciated. Minimum salary $200 per month. Available middle of September. B-9878.

COMMERCIAL ENGINEER, technical graduate, six to seven years' experience in the public utility business on power sales, rates, engineering and operation. Desires responsible position with public utility organization or with firm of consulting engineers. Age 31, excellent health. Available on reasonable notice. Minimum salary $3600. B-9782.

ENGINEERING EXECUTIVE, graduate of two of the best colleges with three years' experience in electric railway activities, thirteen years in the wire and cable industry, now holding responsible position where ability and trustworthiness are essential. Position desired on the Atlantic Seaboard. Should be most successful in a place where he can use his present intimate knowledge of sales, costs and profits, as applied to electric wires and cables. B-9877.

ELECTRICAL ENGINEER, age 32, single, college graduate, Westinghouse student graduate course, designing experience of power plant and substations, also estimating work, is seeking a position with chances for advancement. Speaks foreign languages. Location preferred, New York City or East. B-3993.

ELECTRICAL ENGINEER, B. E. E., married, age 33, desires position where executive and organizing, also engineering ability is required. Ten years' experience power plant, substation design with signal success on control, relay engineering with one of largest public utilities in the country. Pleasantly employed, but desirous of further advance. Available six weeks after signing contract. B-8505.

RESEARCH ENGINEER, five years' experience, qualified to develop small electrical devices, or investigate electrical or mechanical phenomena, wishes to associate with progressive concern or private laboratory. Experience includes radio research, and have several paying devices under way privately. Salary subject to interview. Location immaterial. Available on short notice. B-9869.

GRADUATE ELECTRICAL ENGINEER, B. S. in E. E. 1925, age 27, desires instructorship in college of standing. Six years' experience electrical engineering field in design, installation, estimations; includes two years as executive. Assistant in electrical laboratory while at college. My practical experience enables me to be better acquainted with the needs of the profession. Available September. B-9894.

GRADUATE ELECTRICAL ENGINEER, age 25, single, desires position with public utility or consulting engineer, where executive, as well as engineering ability is required. Sixteen months Test, one and one half years industrial department General Electrical Company. Location, South or West. B-8040.

INDUSTRIAL ENGINEER, electrical and mechanical, age 35, married, specialist design, application, installation of automatic electric control apparatus and devices. Experience also covers railway signal, steam power plant operation, electrical and mechanical construction field: electrical and mechanical draftsman. Reasonable legitimate offers considered. Minimum $225.00. Correspondence solicited. Central West or Southern States only. B-9561.

DRAFTSMAN, age 37, single, sixteen years' experience mechanical and electrical, designer of railroad devices for track and motive power. Available fifteen days' notice. B-9895.

CREATIVE INVENTOR, 21, single, student of sound, heat, light, electricity including radio, mechanics of gases, liquids, solids; vibratory, rotary and wave phenomena; mathematics, chemistry. Desires research work absolutely independent of production of factory with wealthy firm. Advancement so far has been rapid in commercial electrical work (electrical maintenance of large malleable iron foundry for instance). At present employed in radio laboratory, reason for change: dependence of factory on laboratory and limitation of research to radio. Available August 31. Location immaterial. Kindly communicate before June 30th. B 9910.

MEMBERSHIP — Applications, Elections, Transfers, Etc.

ASSOCIATES ELECTED MAY 15, 1925

AIZANMAN, LESTER ELIAS, Operator, Methods Engg. Dept., Western Electric Co., Inc., Emeryville; for mail, Oakland, Calif.

ALIJAN, HAMID, Electrical Foreman, G. I. P. Railway, Parel, Bombay, India.

*ANDERSON, HAROLD R., Electrical Construction Dept., Great Western Power Co., 530 Bush St., San Francisco; res., Berkeley, Calif.

ANDERSON, THEODORE, Electrician, Rogers Pyatt Shellac Co., 39 Essex St., Jersey City; res., Hoboken, N. J.

ARMSTRONG, WILLIAM J., Superintendent, Transformer Dept., Canadian General Electric Co., 1045 Lansdowne Ave., Toronto, Ont., Can.

ASAVAID, ERACHSHAW HORMASJI, Electrical Contractor & Repairer, Erachshaw & Co., Keshav Baug, 112 Princess St., Bombay, India.

AXMACHER, MAX, New York Edison Co., 44 E. 23rd St., New York, N. Y.
*BATES, JOHN WILLIAM, Test Engineer, Duquesne Light Co., Colfax Station, Springdale, Pa.
BINKS, JOHN ERNEST, Construction Foreman, Public Service Production Co. of New Jersey, 53 Pennington St., Paterson, N. J.
*BLENDEN, HENRY ABIJAH, Telephone Engineer, Southwestern Bell Telephone Co., 414 Locust St., St. Louis, Mo.
BORISLAVSKY, MICHAEL A., Freed-Eiseman Radio Corp., Sperry Bldg., Brooklyn, N. Y.
BREAZNELL, JOSEPH GILBERT, Electrical Engineer, Murrie & Co., Inc., Everett Bldg., Union Sq., New York; res., Brooklyn, N. Y.
*BRODY, EDWARD, Electrical Draftsman, Public Service Production Co., 27 Mechanics St., Newark, N. J.; res., Brooklyn, N. Y.
BRUYNING, EUGENE LUDWIG, Radio Engineer, Brytone Radio Laboratories, 310 Broadway, New York, N. Y.
BURNETT, JOHN A., Electrical Construction Dept., Lehigh Coal & Navigation Co., Lansford, Pa.
BURROWAY, ARTHUR CALVIN, Electrical Engineer, Cincinnati & Suburban Bell Telephone Co., Canal Exchange, Race St. & Central Parkway, Cincinnati, Ohio.
CARPENTER, ROYAL CROSBY, Estimator & General Foreman, Bryan Electric Co., 58 Edgewood Ave., Atlanta, Ga.
CARSON, ROLAND WRIGHT, Draftsman, Toronto Hydro System, Duncan & Nelson Sts., Toronto, Ont., Can.
CASCIATI, AGOSTINO MARIO, Electrical Draughtsman, T. E. Murray, Inc., 55 Duane St., New York, N. Y.
*CHAMPE, WILLARD, Assistant, Switchboard Div., Elec. Engg. Dept., Commonwealth Power Corp., Jackson, Mich.
CONGILOSE, FRANK, Generator Tender, Interborough Rapid Transit Co., 59th St. & 11th Ave., New York, N. Y.; res., Hoboken, N. J.
CONREY, DAVID WELLS, Supervising Engineer, So. California Telephone Co., 740 So. Olive St., Los Angeles, Calif.
COPELAND, ROBERT MARION, Partner, Copeland & Copeland, 126 Hutton St., Jersey City, N. J.
*DAVIS, GEORGE PERRIN, Detailer, Underground Dept., Philadelphia Electric Co., 23rd & Market Sts., Philadelphia, Pa.
*DAVIS, HENRY STEWARD, Technical Assistant, Philadelphia Electric Co., 2301 Market St., Philadelphia, Pa.
DAVIS, WILLIAM H., Salesman, Simplex Wire & Cable Co., 15 S DesPlaines St., Chicago, Ill.
*DE RENZIS, JOSEPH A., Central Office Equipment, Western Electric Co., Inc., 1319 F St., N. W., Washington, D. C.; res., New York, N. Y.
ELLIOTT, JOSEPH EVANS, Meter Engineer, Southwestern Gas & Electric Co., Texarkana, Tex; Ark.
FAUNT LEROY, HARRY W., Asst. to the President, Mancha Storage Battery Locomotive Co., 523 Calvert Bldg., Baltimore, Md.
FERTIG, EARL A., Senior Draftsman, Union Gas & Electric Co., Cincinnati, Ohio.
FLITCROFT, FRANK, Transformer Designer, Ferranti Ltd., Hollinwood, Lancashire; res., Oldham, Lancashire, Eng.
FLUCK, EUGENE G., Electrical Engineer, Lawrence Portland Cement Co., Northhampton, Pa.
FOLEY, JOHN GRAHAM, Estimator, Brooklyn Edison Co., Pearl & Willoughby Sts., Brooklyn, N. Y.
FOX, EDWARD COLIN, Certified Electrical Engineer, Richardson-Wayland Electrical Corp., Roanoke, Va.
FOX, HIRAM STANLEY, Division Inspector, Western Union Tel. Co., 800 Brown Bldg., Atlanta, Ga.
FRENCH, WILLIAM PRESTON, Power Station Operator, Puget Sound Power & Light Co., 4545 California Ave., Seattle, Wash.
FUSCO, ALPHONSE ANDREW, Research Laboratory, Freed-Eiseman Radio Corp., 48 Flatbush Ave. Ext., Brooklyn; res., New York, N. Y.
GAILUN, BEN, Electrician, U. S. S. Arizona c/o Postmaster, San Francisco, Calif.
GARNER, LLOYD PRESTON, Electrical Engg. Laboratory, University of Illinois, Urbana, Ill.
GEERTSEN, VICTOR HUGO, Designing Draftsman, Cleveland Union Terminals Co., Cleveland, Ohio.
GERMAIN, GEORGE BAADTE, Instructor, South Dakota School of Mines, Rapid City, S. Dakota.
*GOTODA, KYOICHI, Terashima Hamanocho, Tokushima-shi, Japan.
*GREEN, GEORGE E., Student, Lewis Institute, Chicago, Ill.
GREGORY, CHARLES N., Resident Agent, General Electric Co., 18 Asylum St., Hartford, Conn.
GRENELL, ARTHUR, F., Engineer, Illinois Bell Telephone Co., 212 W. Washington St., Chicago, Ill.
GRINDEL, ODIE V., Operator, Commonwealth Edison Co., 22nd & Fiske Sts., Chicago, Ill.
GROVES, WILLIAM M., Jr., Telephone Engineer, Southwestern Bell Telephone Co., Boatmens' Bank Bldg., St. Louis, Mo.
*GUEST, WESLEY TATE, Lieut., Signal Corps, U. S. A., Camp Alfred Vail, N. J.
GYSI, MAX, Asst. Engineer, Brooklyn Edison Co., Pearl & Willoughby Sts., Brooklyn, N. Y.
*HALEY, HUGH DAVID, Engineer, Motor Engg. Dept., General Electric Co., Lynn; for mail, Clinton, Mass.
HALL, WALTER CHARLES, Engineer, Illinois Bell Telephone Co., 212 W. Washington St.' Chicago, Ill.
HALL, WILLIAM F., Manager, Construction Dept., New York Calcium Light Co., 449 W. 53rd St., New York, N. Y.
HAYES, WINSTON, 802 Powder Springs St., Marietta, Ga.
HEARNE, ALEXANDER WILLIAM, Salesman, W. R. Ostrander & Co., 371 Broadway, New York; res., Brooklyn, N. Y.
HERBERGER, THEODORE R., Valuation Engineer, Murrie Engg. Co., 52 Broadway, New York; res., Brooklyn, N. Y.
HIRSCH, GEORGE OSCAR, Special Tester, General Electric Co., Center St., Lynn; res., West Lynn, Mass.
HOWE, DONALD EVERETT, Fieldman, Southern California Telephone Co., 740 S. Olive St., Los Angeles; res., Long Beach, Calif.
HOWELL, MILLARD T., Electrical Mechanic, Municipal Power & Light, Dist. No. 2, 1347 Wright St., Los Angeles, Calif.
HUNSICKER, OSCAR F., Electrician, Champion Coated Paper Co., Hamilton; res., Trenton, Ohio.
JOHNS, LEONARD SEYMOUR, Engineer, Carrick-Wedderspoon, Ltd., 236 Tuam St., Christchurch, N. Z.
JONES, PERCY HOWSON, Buchanan Rural Telephone Co., Ltd., Telephone Exchange, Buchanan, Sask., Can.
JONES, STANLEY G., Telephone Engineer, Southwestern Bell Telephone Co., Boatmens' Bank Bldg., St. Louis, Mo.
KERR, THOMAS BISHOP, Electrical Engineer, Murrie & Co., 45 E. 17th St., New York; res., Corona, N. Y.
KIGAR, DONALD FRANK, Student, Ohio Northern University, 215 S. Johnson St., Ada, Ohio.
KIRTLEY, CAVE J., Asst. Superintendent of Substations, Pacific Gas & Electric Co., Oakland, Calif.
KLINE, CHARLES A., Valuation Engg. Work, J. L. Murrie Co., 45 E. 17th St., New York, N. Y.; res., Newark, N. J.
KLINGMANN, GEORGE, Electrical Engineer, Dubilier Radio & Condenser Corp., 48 W. 4th St., New York; res., Brooklyn, N. Y.
*KLINKERT, PAUL ANDREW, Electrical Engineer, Wagner Electric Corp., 6400 Plymouth Ave., St. Louis, Mo.
KRASOVEC, RUDOLPH A., Electric Locomotive Engineer, Hudson Coal Co., Vandling, Pa
LANGWIG, FRANK IRVING, Ass't Engineer, Traffic Dept., New York Telephone Co., 158 State St., Albany, N. Y.
*LEON, HAROLD, Radio Material Instpector, Charles Freshman Co., 240 W. 40th St., New York, N. Y.
LITTERST, GEORGE HARRY, Secretary to Vice-President in Charge of Elec. Operation, Public Service Electric & Gas Co., 80 Park Place, Newark N. J.
LITTLE, JOHN PEYTON, Jr., Instructor, Elec. Engg. & Physics Dept., University of Florida, Gainsville, Fla.
LOFTIS, LOUIS CARLISLE, Electrical Contractor, Brevard, N. C.
LYNN, HARRY HOSLER, Valuation Engineer, Murrie & Co., Inc., 52 Broadway, New York; res., New Rochelle, N. Y.
MACK, EDWARD JOHN, Student, New York Electrical School, New York, N. Y.; res., Bayonne, N. J.
MAHAN, WILLIAM J., Electrical Inspector, Building Dept., City of New Haven, City Hall, New Haven, Conn.
MANSON, WALTER BLAINE, Chief Engineer, Holmes Electric Protective Co., 370 7th Ave., New York, N. Y.; res., East Orange, N. J.
*McCREADY, ROBERT IVER, Student, Otis Elevator Co., Yonkers, N. Y.
McLAUGHLIN, JAMES L., Research Engineer (Radio), Precise Mfg. Corp., 254 Mill St., Rochester, N. Y.
*MIDDLETON, RICHARD A., Superintendent of Shop, Joseph T. Fewkes, 137 N. 12th St., Philadelphia, Pa; res., Westville, N. J.
MILLER, DEWEY B., Instructor, Coyne Electrical School, 1300 W. Harrison St., Chicago, Ill.
*MONTGOMERY, TERRYL B., Service Engineer, Westinghouse Elec. & Mfg. Co., 2201 W. Pershing Road, Chicago, Ill.
MOORE, WILLIAM CURTIS, Jr., Asst. Engineer, New York Telephone Co., 104 Broad St., New York, N. Y.
*MUSTAFA, SYED, Experiment Dept., Fairbanks Morse & Co., Indianapolis, Ind.
*MYHRE, CONRAD B., Draftsman, Switchboard Engg. Dept., Westinghouse Elec. & Mfg. Co., 221 Vine St., Edgewood, Pa.
NEWBURY, ALLEN WATERMAN, A. C. Engg. Dept., General Electric Co., Schenectady, N. Y.
NYHOLM, CHRISTIAN, Engineer, Jydsk-Telephone Co., Aashus, Denmark; for mail, American Scandinavian Foundation, 25 W 45th St., New York, N. Y.
O'BRYAN, LORIN, General Engineering Laboratory, General Electric Co., Schenectady; res., Scotia, N. Y.
OLIVER, ARNOLD, J., Engineer, Ohio Bell Tel Co., 4300 Euclid Ave., Cleveland, Ohio.
PAPP, ERWIN G., Draftsman, Indianapolis Light & Heat Co., 48 Monument Circle, Indianapolis, Ind.
PETERSON, HALMER A., Transmission Engineer, Sargent & Lundy, Inc., 1412 Edison Bldg., Chicago, Ill.
PFAU, ARNOLD, Jr., Development & Sales Engineer, American Resistor Co., 1023 Cold Spring Ave., Milwaukee, Wis; res., Philadelphia, Pa.
PLENGE, WILLIAM C., Electrician, Croker Electric Co., 22 W. 30th St., New York, N. Y.; res., Morsemere, N. J.
PRESLEY, EVANS EDWARD, Estimator, The New York Edison Co., 327 Rider Ave., New York, N. Y.
*PYLE, WILLIAM ALEXANDER FARIES, Electrical & Radio Business, 2217 Washington, St., Wilmington, Del.
RANDALL, WALTER, Electrical Engineer in Charge, Associated Power Co., Ltd., Charanpur, P. O., Dist. Burdwan, India.
RAPLEY, FREDERIC ARDERN, Koppel Industrial Car & Equipment Co., Koppel, Pa.
*REID, WILLIAM JOSEPH WALTER, Electrical Engineer, Otis Fensom Elevator Co., Victoria Ave., North, Hamilton, Ont., Can.

RHODES, GEORGE LESLIE, Asst. Superintendent, Elec. Engg. Dept., Puebla Tramway, Light & Power Co., Puebla, Pue., Mexico.
SALVEN, SVEN A. L., Insulation Section Motor Engg. Dept., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
*SANDFORT, MARK, Engineer, Engg. Dept., The Pacific Tel & Tel. Co., 835 Howard St., San Francisco, Calif.
SAWYER, MARK A., Protection Engineer, The Pacific Tel. & Tel. Co., 740 S. Olive St., Los Angeles, Calif.
SAYER, HARRY JAMES, Electrician, Jarvis Electric Co., Vancouver, B. C., Can.
SCHLACKS, HENRY VALENTINE, Lineman, City of Chicago, City Hall, Chicago; res., Oak Park, Ill.
SETTOON, LUTHER LIONEL, Chief Engineer, Electric Plant, United Fruit Co., Bocas Del Toro, Panama.
SHAIFER, CHARLES W., General Engg. Laboratory, General Electric Co., Schenectady, N. Y.
SHAPIRO, MAURICE H., Engg. Dept., Brooklyn Edison Co., Brooklyn;res., New York, N.Y.
*SHEELY, ROBERT ROGERS, Elec. Design, Motor Engg. Dept., Westinghouse Elec. & Mfg. Co., East Pittsburgh; res., Wilkinsburg, Pa.
SHOR, SOL, General Superintendent, Royal SwitchboardCo.,731 3rd Ave., New York, N.Y.
SHORROCK, ERNEST, Sales Engineer, General Electric Co., 84 State St., Boston, Mass.
SHULL, LESTER PHILO, Sales Engineer, Standard Underground Cable Co., 111 W. Washington St., Chicago, Ill.
SINEX, REUBEN THOMAS, Chief Draftsman Puget Sound Power & Light Co., 605 Electric Bldg., Seattle, Wash.
SMITH, GEORGE C., Chief Electrician, Roosevelt Power House, Salt River Valley Water Users Association, Roosevelt, Ariz.
SPILIOS, ANGELOS ATHANS, 225 Meeker Ave., Newark, N. J.
*STERN, SANDER, Electrical Engineer, Experimenter Publishing Co., 53 Park Place, New York, N. Y.
*STONESTREET, NICHOLAS VOLNEY, Philadelphia Electric Co., Philadelphia, Pa.
STRAHAN, ROBERT BARTON, 189 Roseville Ave., Newark N. J.
TAINTOR, CHARLES WILSON, Consulting Engineer, Gila Valley Power Dist., Yuma, Ariz.
TAYLOR, EDWARD ABRAHAM, Engineer & First Asst. to Mgr., Turnbull & Jones, Ltd., Wellington, N. Z.
TERRELL, LOWELL S., Inspector, Western Union Tel. Co., 800 Brown Bldg., Atlanta; res., College Park, Ga.
TILLOTSON, PAYSON MOODY, Inspector, Elec. Engg. Dept., Edison Electric Illuminating Co., 39 Boylston St., Boston, Mass.
*TZOUGROS, GEORGE JOSEPH, Testing Laboratory, Public Service Co. of New Jersey, 21st & Clinton Aves., Newark, N. J.
VAN EYK, PAULUS, Power Plant Dept., New York Telephone Co., 227 E. 30th St., New York, N. Y.
*VELASCO, JOSE, Jr., Engineering Inspectors' Assistant, Milwaukee Electric Railway & Light Co., Milwaukee, Wis.
VOGEL, PETER J., Chief Load Dispatcher, Dept. Public Service, City of Los Angeles, Los Angeles, Calif.
VOLKMANN, ERNST, E. H. T., Switchgear Designer, Ferguson Pailin, Ltd., Higher Openshaw, Manchester; res., Gorton, Manchester, Eng.
VOLLMER, KARL JOSEPH, Transformer Tester, Moloney Electric Co., 7th & Hickory Sts., St. Louis, Mo.
*WALLIN, MARINO RAYMOND, Junior Distribution Engineer, Union Electric Light & Power Co., 315 N. 12th St., St. Louis, Mo.
WEEKS, ORVILLE B., Inspector, Murrie & Co., 45 E. 17th St., New York; res., Brooklyn, N.Y.
WENNERSTROM, ALBERT WILLIAM, Asst. Toolroom Foreman, General Electric Co., Erie, Pa.
WHITE, THOMAS CONKLIN, Asst. Electrical Supt., McClellan & Junkersfeld, Inc.; Cahokia Power Plant, St. Louis, Mo.
WHITEMAN, CLARENCE F., Asst. Supt., Service Dept., Cleveland Electric Illuminating Co., 75 Public Sq., Cleveland, Ohio.
WHITLOCK, C. HUBER, Production Manager, Samson Cutlery Co., 165 St. Paul St., Rochester, N. Y.
WILSON, RAY DEVERE, Load Dispatcher, Ohio Public Service Co., Alliance, Ohio.
WOODS, HORACE JOHN, Electrical Engineer, Missouri Inspection Bureau, 1330 Pierce Bldg., St. Louis, Mo.
YATES, GEORGE ASHTON, Sales Representative, Southwestern Dist., Habirshaw Electric Cable Co., Inc., Yonkers, N. Y.; for mail, 814 Spruce St., St. Louis, Mo.

Total 137

*Formerly Enrolled Students

ASSOCIATES REELECTED MAY 15, 1925

BECHLEM, ALFRED WILLIAM, Instructor, Mech. Engg. Dept., Oregon Agricultural College, Corvallis, Wash.
EARDLEY, MEHRING V., Distribution Dept., Bureau of Power & Light, City of Los Angeles, 1253 W. 7th St., Los Angeles, Calif.
GATI, BELA, Consulting Engineer, Gyali-ut 22, Budapest, 1x, Austria, Hungary.
MENZEL, ALBERT FRANKLIN, Dist. Superintendent, Caribou Plant, Great Western Power Co., Caribou, Calif.
NAGEL, HARRY L., New Business Dept., Wagner Electic Corp., 6400 Plymouth Ave., St. Louis, Mo.
PYLE, JOHN CLIFFORD, Dist. Sales Agent, Standard Underground Cable Co., 319 Citizens National Bank Bldg., Los Angeles, Calif.
THISTLEWHITE, ROBERT, Teacher, Dept. of Electricity, Jefferson High School, 38th & Compton Aves., Los Angeles, Calif.

ASSOCIATES REINSTATED MAY 15, 1925

STEWART, DAVID W., Resident Engineer, Power Station, Waipori Falls, Dunedin, New Zealand.

MEMBERS REELECTED MAY 15, 1925

KNOWLTON, FREDERIC K., President, M. D. Knowlton Co., & Auburn Ball Bearing Co., 29 Industrial St., Rochester, N. Y.

MEMBERS ELECTED MAY 15, 1925

GUY, DAVID J., Engineer, Federal Power Commission, Washington, D. C.
LARKIN, DAVID, President, Larkin Engineering Co., 424 N. 3rd St., St. Louis, Mo.
MASENG, OLAV, Commercial Engineer, Westinghouse Elec. & Mfg. Co., East Pittsburgh; res., Pittsburgh, Pa.
TERWILLIGER, CHARLES VAN ORDEN, Asst. Professor, Robinson Laboratory, Ohio State University, Columbus, Ohio.

TRANSFERRED TO GRADE OF FELLOW MAY 15, 1925

HARRISON, JAMES Engineer, General Engineering Dept., Southwestern Bell Telephone Co., St. Louis, Mo.
PORSKIEVIES, ANTHONY J., Motor Engineer, Electric Controller & Manufacturing Co., Cleveland, Ohio.

TRANSFERRED TO GRADE OF MEMBER MAY 15, 1925

AMSTUZ, J. O., Electrical Engineer, El. Railroad Soleure-Berne, Soleure, Switzerland.
JENNINGS, F. R., Manager & Owner, F. R. Jennings Co., Detroit, Mich.
ORCUTT, DANIEL P., Assistant Manager, Electric Storage Battery Co., New York, N. Y.
REHMAN, NORMAN J., Assistant Engineer, New York Telephone Co., New York, N. Y.
SIDLE, WALTER P., Bridgeport Service Manager, Westinghouse Electric & Mfg. Co., Bridgeport, Conn.
STAFFORD, HARRY E., Electrical Engineer, Provincial Paper Mills Ltd., Port Arthur, Ont.
WHITEFILED, WILLIAM I., Superintendent, Lighting & Power, Roanoke Railway & Electric Co., Roanoke, Va.

RECOMMENDED FOR TRANSFER

The Board of Examiners, at its meeting held May 11, 1925, recommended the following members for transfer to the grade of membership indicated. Any objection to these transfers should be filed at once with the Secretary.

To Grade of Fellow

CREIGHTON, ELMER E. F., Engineer on Inventions & Developments, General Electric Co., Schenectady, N. Y.
DRAKE, HERBERT W., Apparatus Engineer, Western Union Telegraph Co., New York.
JONES, JOSEPH S., Vice-President, General Manager & Director of Engineering, Charles Cory & Son, Inc., New York.
YOUNG, HERBERT W., President, Delta-Star Electric Co., Chicago, Ill.

To Grade of Member

ATKINSON, GEORGE W., Superintendent, Power & Maintenance, Gilbert & Barker Mfg. Co., Springfield, Mass.
BATTEY, W. R., Designing Engineer, Southern California Edison Co., Los Angeles, Calif.
BLAIR, HOMER O., Consulting Engineer, Tacoma, Wash.
DAHL, OTTO G. C., Instructor in Electrical Engineering, Massachusetts Institute of Technology, Cambridge, Mass.
DARROW, WIRT E., Telephone Development Engineer, American Telephone & Telegraph Co., New York.
DEININGER, HARRY W., Asst. General Manager, General Superintendent, & Chief Engineer, Iowa Southern Utilities Co., Centerville, Ia.
FLANIGEN, JOHN M., Distribution Engineer, Ohio Public Service Co., Warren, Ohio.
HAINES, WILLIAM H., Sales & Designing Electrical Engineer, Electric Specialty Co., Stanford, Conn.
HOLTZ, F. C., Chief Engineer, Sangamo Electric Co., Springfield, Ill.
HOWARD, LAWRENCE F., Central Office Engineering, American Telephone & Telegraph Co., New York.
LOVETT, I. H., Associate Professor of Electrical Engineering, University of Missouri, Rolla, Mo.
MacTAVISH, HERBERT JAMES, Secretary, Toronto Electric Commissioners, Toronto, Ont.
PATTON, PAUL H., Telephone Engineer, Omaha, Neb.
SCHWARTZ, BEN, Representative & Sales Engineer, Holophane Glass Co., St. Louis, Mo.
SCOVEL, H. W., Engineer, Electrical Division, Illinois Power & Light Corp., Chicago, Ill.
SEARING, HUDSON R., Assistant Electrical Engineer, United Electric Light & Power Co., New York.
SHORT, FRANK A., Electrical Engineer, Safety Electric Products Co., Los Angeles, Calif.
THOMASON, JOSEPH J., Street Lighting Engineer, Westinghouse Electric & Mfg. Co., St. Louis, Mo.
VEDDER, WILSON Y., Meter Engineer, Brooklyn Edison Co., Brooklyn, N. Y.
VOGAN, FRANK C., Consulting Engineer, Philadelphia, Pa.
WARFIELD, GILMER A., Commercial Engineer of Automatic Substations, Westinghouse Electric & Mfg. Co., Pittsburgh, Pa.
WATT, HAROLD W., Electrical Engineer, Westchester Lighting Co., Yonkers, N. Y.

APPLICATIONS FOR ELECTION

Applications have been received by the Secretary from the following candidates for election to membership in the Institute. Unless otherwise indicated, the applicant has applied for admission as an Associate. If the applicant has applied

for direct admission to a higher grade than Associate, the grade follows immediately after the name. Any member objecting to the election of any of these candidates should so inform the Secretary before June 30, 1925.

Ambelang, C. E., Public Service Co. of No. Illinois, Chicago, Ill.
Anderson, E. C., Ware Radio Corp., New York, N. Y.
Aschemeyer, E., Cohokia Sta., Union Elec. Lt. & Pr. Co., East St. Louis, Ill.
Atkins, J. J., Cleveland Electric Mfg. Co., Cleveland, Ohio
Atwood, H. S., Puget Sound Power & Light Co., Everett, Wash.
Badcock, W., British Columbia Electric Railway Co., Lake Buntzen, Burrard Inlet, B. C.
Ballock, R. H., Light & Water Dept., City of Tacoma, Tacoma, Wash.
Bash, T. B., (Member), Kansas City Power & Light Co., Kansas City, Mo.
Bates, F. M., (Fellow), Consulting Electrical Engineer, Philadelphia, Pa.
Baus, R.A., Penn Allen Cement Co., Nazareth, Pa.
Bayly, B. deF., Student-at-Law, Moose Jaw, Sask., Can.
Beardsley, E. H., Cleveland Elec. Illuminating Co., Cleveland, Ohio
Bergman, G. E., Puget Sound Power & Light Co., Seattle, Wash. (Applicant for re-election)
Blagoveschensky, L. N., Brooklyn Edison Co., Brooklyn, N. Y.
Bleackley, R., Repair Engr. & Elec., City of Swift Current, Saskatchewan, Can.
Blume, N. H., Wisconsin Telephone Co., Madison, Wis.
Bouillon, L., Stone & Webster, Seattle, Wash.
Bourke, A. M., Public Service Co. of No. Illinois, Streator, Ill.
Boyd, G. M., Westinghouse Elec. & Mfg. Co., Seattle, Wash.
Boynton, E. J., Murrie Engineering Co., New York, N. Y.
Bray, Marguerite M., Pacific Portland Cement Co., Cement, Calif.
Brickett, J. E., Auto. Mechanic, Central Fire Hall, Moose Jaw, Sask., Can.
Brown, J. E., Westinghouse Elec. & Mfg. Co., Los Angeles, Calif.
Brown, L. E., Public Service Co. of No. Illinois, Chicago, Ill. (Applicant for re-election)
Brown, L. F., Los Angeles Railway Corp., Los Angeles, Calif.
Brownell, F. W., Puget Sound Power & Light Co., Seattle, Wash.
Buckingham, E. W., Murrie & Co., Inc., New York, N. Y.
Buckley, H. P., Murrie & Co., New York, N. Y.
Burchett, C. R., New York Rapid Transit Corp., Brooklyn, N. Y.
Burke, G. E., Public Service Electric & Gas Co., Passaic, N. J.
Burke, J. H., Scranton Electric Co., Scranton, Pa.
Burleigh, J. A., Pacific Tel. & Tel. Co., Seattle, Wash.
Bussard, E. J. H., The Crosley Radio Corp., Cincinnati, Ohio
Callahan, R. G., Chicago Surface Lines, Chicago, Ill.
Campbell, H. R., Lehigh Valley Railroad Co., Sayre, Pa.
Canary, J. F., New Amsterdam Gas Co., Long Island City, N. Y.
Carroon, W. E., Jr., New Mexico State College, State College, New Mex.
Carter, H. H., Philadelphia Electric Co., Philadelphia, Pa.
Chase, C. H., (Member), Brooklyn Edison Co., Brooklyn, N. Y.
Chute, G. M., Jr., General Electric Co., Schenectady, N. Y.
Clark, A. B. M., British Columbia Electric Railway Co., Stave Falls, B. C.
Clark, H. R., Eisemann Magneto Corp., Brooklyn, N. Y.
Clark, R. W., Puget Sound Power & Light Co., Seattle, Wash.
Cole, F.A., New York Telephone Co., Newark, N.J.
Cooper, C. W., Public Service Co. of No. Illinois, Waukegan, Ill.
Covey, A. B Southwestern Bell Tel. Co., St., Louis, Mo.
Coward, A. B., Light & Power Dept., Regina, Sask., Can.
Cowley, J. R., City Electrical Engineer, City Hall, Saskatoon, Sask., Can.
Crooke, R. R., NePage & McKenny Co., Seattle, Wash.
Curtis, H. M., C. & P. Electric Works, Springfield, Mass.
Davies, P. M., Southern California Telephone Co., Los Angeles, Calif.
Dethridge, S. G., City Municipal Elec. Lt. Plant, Regina, Sask., Can.
Deutsch, R., Pratt Institute of Technology, Brooklyn, N. Y.
Dick, W., Puget Sound Power & Light Co., Seattle, Wash.
Dippel, F. W., Wisconsin Telephone Co., Milwaukee, Wis.
Dundatscheck, L., New York Tel. Co., New York, N. Y.
Eicher, H. L., Eicher & Bratt, Seattle, Wash.
Ellsworth, P. R., Cleveland Elec. Illuminating Co., Cleveland, Ohio
Farmer, W. M., Electric Bond & Share Co., New York, N. Y.
Faulkner, C. F., So. California Tel. Co., Los Angeles, Calif.
Fernandez, G., General Electric Co., Mexico, D. F., Mex.
Finn, J. A., Public Service Production Co., Paterson, N. J.
Firth, B. H., Pratt Institute, Brooklyn, N. Y.
Foltz, L. S., (Member), Michigan State College, East Lansing, Mich. (Applicant for re-election)
Ford, A. H., Western Public Service Co., Downers Grove, Ill.
Frankenfield, P. T., Jacoby & Everett, Allentown, Pa.
Gaisman, A., Tampico Electric Co., Tampico, Tamps., Mex.
Gamble, R. E., Preston & Bishop, Inc., Holyoke, Mass.
George, R., General Electric Co., Philadelphia, Pa.
Gillern, M. F., Sierra Electric Co., Inc., Los Angeles, Calif.
Grant, L. R., Puget Sound Power & Light Co., Seattle, Wash.
Greer, S., British Columbia Electric Railway Co., Stave Falls, B. C.
Gustafson, C. W., Mutual Fire Prevention Bureau, Chicago, Ill.
Hague, J. H., Westinghouse Elec. & Mfg. Co., East Springfield, Mass.
Hanley, J. F., Electrical Testing Laboratories, New York, N. Y.
Harkness, W. E., (Member), Brooklyn Edison Co., Brooklyn, N. Y.
Hawe, J.E., Stone & Webster, Inc., Seattle, Wash.
Heavers, W., Public Service Co. of No. Illinois, Lacon, Ill.
Heimburger, H. A., The Wagner Electric Corp., Springfield, Mass.
Hood, G. D., Rock Island Lines System, Chicago, Ill.
Husted, E. W., Tower Binford Electric & Mfg. Co., Richmond, Va.
Hyan, G., Detroit Edison Co., Detroit, Mich.
Jacobs, M. F., Public Service Co. of No. Illinois, Chicago, Ill.
Jackson, F. P., Jackson's Engineering Laboratories, Waco, Texas
Janssen, H. W., International Elec. & Machinery Co., Los Angeles, Calif.
Jensen, A. G., Bell Telephone Laboratories, Cliffwood, N. J.
Jervey, W. E., Jr., Southeastern Underwriters Ass'n., Atlanta, Ga.
John, E., School of Engineering of Milwaukee, Milwaukee, Wis.
Judd, P. C., Murrie & Co., New York, N. Y.
Jungwirth, I. A., Public Service Elec. & Gas Co., Passaic, N. J.
Kasak, A. J., Electric Bond & Share Co., New York, N. Y.
Keast, P., Empire Mines, Grass Valley, Calif.
Keegan, W. G., Electrical Contracting, Los Angeles, Calif.
Kelly, W., (Fellow), Director of Engg., N. E. L. A., New York, N. Y.
Kilgour, C. E., Crosley Radio Corp., Cincinnati, Ohio
King, J. T., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Klenke, J., Jr., General Electric Co., Schenectady, N. Y.
Knight, F. D., (Member), Edison Elec. Illuminating Co., Boston, Mass.
Kurtz, H., New York Edison Co., New York, N.Y.
LaPoe, A., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Larson, A. J., Public Service Co. of No. Illinois, Waukegan, Ill.
Lauber, F. H., Baltimore Copper, Smelting & Rolling Co., Baltimore, Md.
Lauer, F. O., Westinghouse Elec. & Mfg. Co., Wilkes-Barre, Pa.
Lees, R., Wiring Inspector & Meter Supt., City of Moose Jaw, Moose Jaw, Sask., Can.
Little, T. J., Anaconda Copper Mining Co., Chicago, Ill.
Lloyd, T. M., Eiseman Magneto Corp., New York, N. Y.
Loofbourow, J. R., Crosley Radio Corp., Cincinnati, Ohio
Louret H. A., Commonwealth Edison Co., Chicago, Ill.
Ludasy, A., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Marchanton, A. E., British Columbia Electric Railway Co., Stave Falls, B. C.
Marten, C. A., Western Electric Co., Inc., Seattle, Wash.
Martin, H.L., Wagner Electric Corp., St.Louis, Mo.
Martin, J., American Bureau of Shipping, New York, N. Y.
Meek, H. K., New England Tel. & Tel. Co., Boston, Mass.
Merkle, A. J., Southwest Power Co., McAlester, Okla.
Meyer, F.C., New York Telephone Co., Newark, N.J.
Miller, L. H., Brooklyn Edison Co., Brooklyn, N.Y.
Molin, J. E., Public Service Co. of No. Illinois, Chicago Heights, Ill.
Monroe, W. S., (Fellow), Sargent & Lundy, Inc., Chicago, Ill.
Moore, C. A., Elec. Supt., Town of Assiniboia, Saskatchewan, Can.
Munro, J., British Columbia Electric Railway Co., Ltd., Vancouver, B. C.
Nelson, G. W., Chicago Surface Lines, Chicago, Ill.
Newton, W. H., Puget Sound Power & Light Co., Seattle, Wash.
Nichols, J.J., Bell Telephone Co., Philadelphia, Pa.
Nicholson, A. H., Cleveland Electric Illuminating Co., Cleveland, Ohio
Nilsson, J. L., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
O'Connell, E. J., American Tel. & Tel. Co., Chicago, Ill.
O'Connor, J., Cleveland Electric Illuminating Co., Cleveland, Ohio
Orton, D. L., Cleveland Railway Co., Cleveland, Ohio
Otto, E. A., General Electric Co., Pittsfield, Mass.
Peters, J. D., (Member), Electric Light & Power Dept., City of Moose Jaw, Moose Jaw, Sask., Can.
Pike, N., Cia Westinghouse Elec. Internacional, Mexico, D. F., Mex.
Porter, F. J., Jr., General Electric Co., Schenectady, N. Y.
Porter, R. G., School of Engg., Northeastern Univ., Boston, Mass.
Pratt, E. J., (Member), Bell Telephone Laboratories, Inc., New York, N. Y.
Ramrath, J., William H. Taylor & Co., Allentown, Pa.
Ray, M. C., Cleveland Electric Illuminating Co. Cleveland, Ohio
Reed, C. L., Jr., 254 Penn St., Huntingdon, Pa.
Richardson, W. L., Stone & Webster, Inc., Seattle, Wash.
Riordan, J. F., United Electric Light & Power Co., New York, N. Y.
Rives, H. D., Delta Star Electric Co., New York, N. Y.
Robb, H. W., General Electric Co., Schenectady, N. Y.

Rohr, C. S., Stone & Webster, Inc., Seattle, Wash.
Rosen, M., Chicago Surface Lines, Chicago, Ill.
Ross, W. S., Asst. to Alfred I. Phillips, New York, N.Y.
Rotsel, F. C., City of Los Angeles Bureau of Pr. & Lt., Los Angeles, Calif.
Ryder, E. A., Southern Bell Tel. & Tel. Co., Charlotte, N. C.
Sachse, A. O., Public Service Production Co., Newark, N. J.
Sanderrock, H. H., Moose Jaw Battery Service, Moose Jaw, Sask., Can.
Schooley, G. G., Kansas City Power & Light Co., Kansas City, Mo.
Shannon, W. D., Stone & Webster, Inc., Seattle, Wash.
Simpson, H. T., Edison Electric Illuminating Co., Wilmington, Mass.
Smith, N. E., Philadelphia Electric Co., Philadelphia, Pa.
Snow, O. F., French Telegraph Cable Co., Orleans, Mass.
Snyder, O., (Member), Adirondack Power & Light Co., Schenectady, N. Y.
Speidel, C. A., Pratt Institute, Brooklyn, N. Y.
Springer, H. E., Stone & Webster, Seattle, Wash.
Stansbury, C., Cutler-Hammer Mfg. Co., Milwaukee, Wis.
Stokes, H. D., Electrical Contracting, 142 McKinley St., Rochester, N. Y.
Stukey, D. C., Public Service Co. of No. Illinois, Pontiac, Ill.
Sullivan, R. T., Tacoma Railway & Power Co., Tacoma, Wash.
Swaezey, I. E., International Motor Co., Plainfield, N. J.
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Thornhill, C. P., with R. F. Taylor, Dallas, Texas
Timanus, W. R., Davison Chemical Co., Curtis Bay, Md.
Titus, E. S., Allis-Chalmers Mfg. Co., Benton Harbor, Mich.
Torpen, B. E., Cushman Pr. Project, City of Los Angeles, Los Angeles, Calif.
Torrance, D. J., Puget Sound Power & Light Co., Seattle, Wash.
Town, C. P., Power Plant, Swift Current, Sask., Can.
Trowbridge, H.V., FarmManager, Willamania, Ore.
Van Luven, H. H., Sierra Electric Co., Inc., Los Angeles, Calif.
Verally, J., Draftsman, 1998 Madison Ave., New York, N. Y.
Vielmetti, C. A., Public Service Co. of No. Illinois, Evanston, Ill.
Villamena, V. W., New York Edison Co., New York, N. Y.
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Waters, E. G., The California Oregon Power Co., Medford, Ore.
Watson, J. C., Commonwealth Edison Co., Chicago, Ill.
Weber, G. L., Pacific Tel. & Tel. Co., Sacramento, Calif.
Wehrenberg, W., Jr., United Electric Light & Power Co., New York, N. Y.
Wendt, K. G., Public Service Co. of No. Illinois, Kankakee, Ill.
Wetzel, M. T., Public Service Co. of No. Illinois, Chicago, Ill.
White, P. W., Illinois Bell Telephone Co., Chicago, Ill.
Wild, S. J., Western Electric Co., Inc., Emeryville, Calif.
Willard, A.C., Duquesne LightCo., Pittsburgh, Pa.
Williams, E. A., American Electric Works, Columbus, Ohio
Williams, E. C., Public Service Co. of No. Illinois, Chicago, Ill.
Williamson, E. W., Industrial Electrical Service Co., Aberdeen, Wash.
Wilson, J. L., American Bureau of Shipping, New York, N. Y.
Wolff, W., Public Service Co. of No. Illinois, Evanston, Ill.
Wright, M. L., Public Service Co. of No. Illinois, Chicago, Ill.
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Yamashita, K., Oakland Polytechnic College of Engg., Oakland, Calif.
Young, F. C., PacificTel. & Tel. Co., Seattle, Wash.
Younger, J. R., Public Service Production Co., Kearny, N. J.
Zeller, A. J., Copper Queen Branch, Phelps-Dodge Corp., Bisbee, Ariz.
Zerber, W. E., Cass Technical High School, Detroit, Mich.
Zimmele, E. M., New York University, New York, N. Y.
Total 197

Foreign

Fukawo, E., Bureau of Elec., Dept. of Communications, Tokyo, Japan.
Harber, F. O., Metropolitan Vickers Elec. Co., Ltd., Manchester, Eng.
Kato, K., Bureau of Elec., Dept. of Communications, Tokyo, Japan.
Markman, F., Allmanna Telefonaktiebolaget, Stockholm, Sweden
Marks, E., Automobile Elec. Sup., Willard Service Sta., Johannesburg, S. A.
Mena, A. J., Porto Rico Railway, Light & Power Co., San Juan, P. R.
Munn, S. A., Engg. Staff, The City Improvement Co., Santos, Braxil, S. A.
Noerr, A. E., Noerr Electric Service, Suva, Fiji Islands
Pinero, G., Porto Rico Railway, Light & Power Co., San Juan, P. R.
Total 9

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Caldwell, Gordon G., University of California
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Dutton, Ralph A., Georgia School of Technology
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Hendricks, J. Walter, Jr., Georgia School of Tech.
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Howe, Francis R., University of California
Howell, William D., Michigan State College of A. & A. S.
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Leipziger, Joseph, College of the City of New York
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*CHARLES P. STEINMETZ, 1901-2.
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BION J. ARNOLD, 1903-4.
JOHN W. LIEB, 1904-5.
*SCHUYLER SKAATS WHEELER, 1905-6.
*SAMUEL SHELDON, 1906-7.
*HENRY G. STOTT, 1907-8.
LOUIS A. FERGUSON, 1908-9.
LEWIS B. STILLWELL, 1909 10.
DUGALD C. JACKSON, 1910-11.
GANO DUNN, 1911-12.
RALPH D. MERSHON, 1912-13.
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PAUL M. LINCOLN, 1914-15.
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E. W. RICE, JR., 1917-18.
COMFORT A. ADAMS, 1918-19.
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A. W. BERRESFORD, 1920-21.
WILLIAM McCLELLAN, 1921-22.
FRANK B. JEWETT, 1922-23.
HARRIS J. RYAN, 1923-24.

*Deceased.

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Charles le Maistre, 28 Victoria St., London, S. W. 1, England.
A. S. Garfield, 45 Bd. Beausejour, Paris 16 E, France.
H. P. Gibbs, Tata Sons Ltd., 24 Bruce Road, Bombay—1, India.
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NEW CATALOGUES AND OTHER PUBLICATIONS

Mailed to interested readers by issuing companies

Automatic Starters.—Bulletin 799, 20 pp. Describes "E-M" automatic starters for synchronous motors, and includes a list of users of "E-M" apparatus. Electric Machinery Mfg. Company, Minneapolis, Minn.

Brushes.—Bulletin 110, "Brushes for Rotary Converters." Describes manufacture, efficiency and application of collector ring and commutator brushes. Kohlenite Products Co., Inc., 417 West 38th St., New York.

Automatic Arc Welding.—Bulletin 48937.1, 20 pp. Outlines the uses and value of automatic arc welding, together with a description of welding apparatus and generating equipment. General Electric Company, Schenectady, N. Y.

Ball Bearing Data.—In addition to the regulation information, new SRB Data Sheets contain shaft and housing bore limits, equivalent tables and other special information, helpful in properly applying ball bearings to various types of equipment. Standard Steel and Bearings, Inc., Plainville, Conn.

Circuit Breakers.—Bulletin 530, 4 pp. Describes a new non-closable on overload circuit-breaker recently brought out by the Roller-Smith Company, 12 Park Place, New York. It has been designed to fill a need for a free handle breaker, low in price, free from complications and applicable to all the various styles of breakers made by the company.

Electrical Resistance Thermometers.—Bulletin 12, 16 pp. Describes Thwing electrical resistance thermometers, indicating and multiple-recording types, and their many applications to the various industries, especially designed for measuring temperatures from 273° C. to 200° C., and in special cases to 425° C. Thwing Instrument Company, 3339 Lancaster Ave., Philadelphia, Pa.

Arc Welded Buildings.—Bulletin 4657, 8 pp. Describes how the Chicago, Burlington and Quincy Railroad successfully constructed steel buildings entirely with arc welded joints. Illustrations are shown of the building at various stages of construction, and comparison is made of the erection costs of arc welded buildings with those of riveted buildings. The Westinghouse Electric & Mfg. Company, East Pittsburgh, Pa.

Transformers.—Bulletin 2043, 4 pp. Describes Pittsburgh expansion tank type transformers. Such transformers are equipped with a main tank, which is completely filled with oil, and an auxiliary tank provided to allow for expansion and contraction of the oil, so that any moisture or dirt may be prevented from entering the main transformer tank. Pittsburgh Transformer Company, Columbus & Preble Aves., Pittsburgh, Pa.

Distant Instrument Dials.—Bulletin 69, 8 pp. Such dials are used with watthour meters for duplicating at a convenient location, the reading of the meter register, for totalizing the revolutions or strokes of engines, generators, or other machines; or for summing on a single dial the total registration of a group of watthour meters. The distant dials are made in two types—for operation on direct current and for operating on alternating current. The Sangamo Electric Company, Springfield, Ill.

Small D-C. Instruments.—Bulletin 400, 8 pp. Describes two lines of small d-c. panel type instruments, types TD and FD ammeters, milliammeters, voltmeters, millivoltmeters and voltammeters. The type TD is 3½ in. in diameter and the type FD 4 in. These instruments, intended particularly for radio sets, battery eliminators, chargers, X-Ray apparatus, alarm systems and small panels of all kinds, employ the d'Arsonval mechanism. Roller-Smith Company, 12 Park Place, New York.

Push Button Oil Switch.—Bulletin 1048, 8 pp. Describes a new push button operated oil switch for starting squirrel cage motors, and also single phase motors. The switch throws the motor across the line when the "start" button is pressed; it is arranged for no-voltage protection or no-voltage release, as desired, and provides overload and phase failure protection by means of expansion wire temperature relays. The Electric Controller & Mfg. Company, 2700 E. 79th St., Cleveland, Ohio.

NOTES OF THE INDUSTRY

The Acme Wire Company, New Haven, Conn., has moved its Chicago sales office from 53 West Jackson Boulevard, to 427 West Erie Street, where a stock of all Acme wire products is being carried.

Sharples Specialty Company, Philadelphia, announces that a new Pacific coast office has been opened at 688 Howard Street, San Francisco, under the name of the Sharples Specialty Company of California. L. S. Taylor will be in charge of this territory.

The W. N. Matthews Corporation, St. Louis, manufacturers of electrical specialties and mechanical painting equipment, announces that G. Carl Kemper has just joined the company's advertising department, as assistant to the general sales manager, who supervises the advertising activities of the company. Mr. Kemper is well known in advertising circles and was recently elected president of the Junior Advertising Club of St. Louis.

New Welding Generator.—The Electric Arc Cutting & Welding Company, Newark, N. J., has developed a new welding generator including certain features not heretofore incorporated in such apparatus. Both alternating and direct current can be obtained through the use of this generator, so that either may be employed for welding work. An important feature of the generator is that either the a-c. or d-c. leads can be short-circuited at the collector rings or commutator without injury.

Capital Stock of G-E Company Increased.—The stockholders of the General Electric Company at a recent meeting voted to increase the capital stock of the company from $220,000,000, consisting of 1,850,000 shares of common stock of the par value of $100 each, and 3,500,000 shares of special stock of the par value of $10 each, to the amount of $240,000,000, consisting of 1,850,000 shares of common stock of the par value of $100 each, and 5,500,000 shares of special stock of the par value of $10 each. The twenty directors were reelected for the ensuing year.

Condit Electrical Manufacturing Company Expands.—The Condit Electrical Mfg. Company, Boston, Mass., has purchased a 15 acre tract, with two brick buildings covering about 200,000 sq. ft. of floor space, at Hyde Park, Mass., served with spur track from the main line of the N. Y., N. H. & H. R. R., and is now completing a new brick building on the property, about 22,000 sq. ft. and 40 ft. high. During the summer various manufacturing activities will be housed in these buildings in addition to the facilities now utilized at the company's plant at 838 Summer St., South Boston, where the main offices of the company will remain.

Triumph Electric Company Declared Solvent.—As a result of a directed verdict in the United States Court at Dayton, Ohio, a judgment order was entered recently declaring the Triumph Electric Company not a bankrupt, and dismissing the petitions of three creditors. This verdict ends a long drawn out litigation involving the Triumph Electric Company, a million-dollar company, engaged in motor manufacture at Cincinnati, Ohio., in a possible process of bankruptcy. The three creditors alleged that the company was indebted to them in the amount of $2200, and that the company's liabilities exceeded the assets by $70,000. The electric company produced figures to show that its assets exceeded its liabilities by $500,000.


From the Early Period
of the Telegraph to the present
remarkable development in the field of Electricity
KERITE
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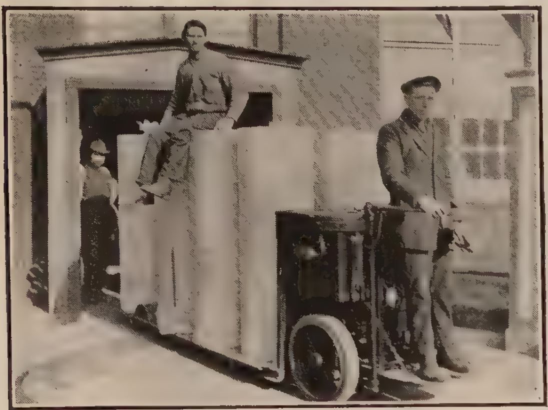
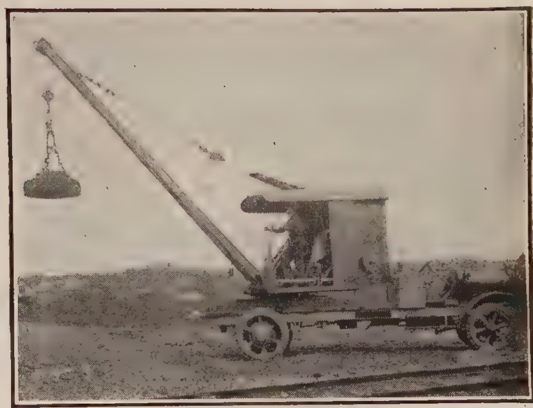
fact that it is the most reliable and
permanent insulation known
KERITE INSULATED WIRE & CABLE COMPANY
NEW YORK CHICAGO
DAYS KERITE

Advantages of Ball Bearings for Electric Motors



Electrically driven factory truck

Sixth of a series of advertisements appearing monthly in this magazine summarizing the advantages of ball bearings for electric motors.



Motor truck with crane magnet operated electrically

Coal loader with electric motor

Mechanical shovel with electric motor

VI. Thrust load capacity

The importance of having armature bearings capable of carrying a moderate thrust load is often minimized. In vertical motors, of course, this requirement is conceded and ball bearings generally adopted on this account. As a matter of fact, thrust carrying capacity is almost as important in a horizontal motor.

These motors are often in use on movable or portable units, similar to those illustrated, where the motor is constantly being tilted or shaken sideways. This throws the weight of the armature directly on the bearings, often, as on the coal loader, for a considerable length of time.

Plain bearings cannot carry this possible thrust load for any time without special thrust washers. These mean extra expense and added friction, or, if no such provision is made, the chance that the motor may be subjected to a thrust load it cannot stand.

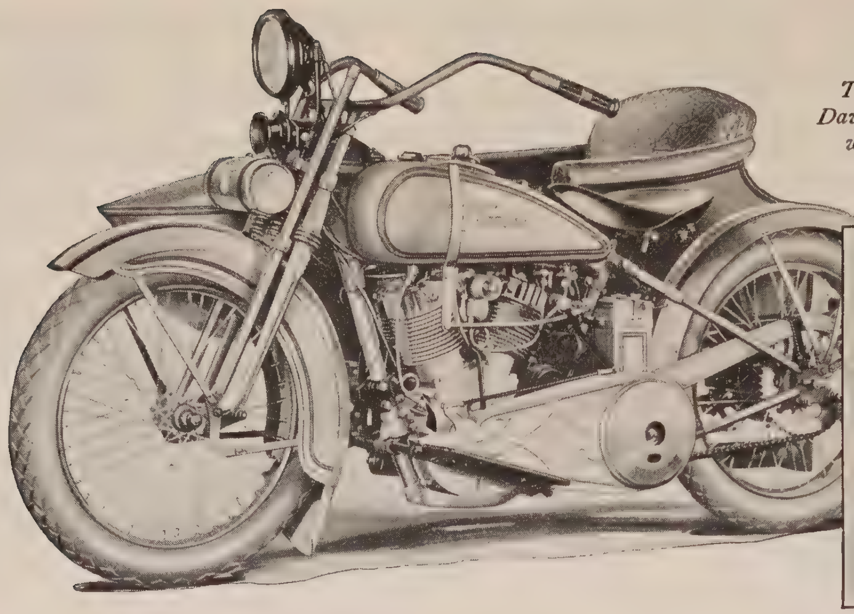
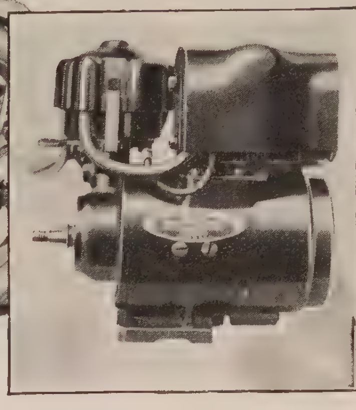
A single row radial ball bearing, such as is generally used in horizontal motors, will carry any thrust conceivable on this service. This insures a horizontal motor against thrust loads under all conditions.

The Fafnir Bearing Company

Detroit **New Britain, Conn.** **Chicago**

Makers of high grade ball bearings—
the most complete line of types and sizes in America.

FAFNIR
BALL BEARINGS

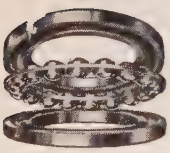



The generator of the Harley-Davidson Motor Cycle is equipped with Strom Ball Bearings.

5 Important Reasons

—why Strom Ball Bearings are standard equipment in many types of electric generators

Double-acting thrust bearing, flat seats (grooved races) 1100-F Series



Single-acting thrust bearing, flat seats (grooved races) 1100-F Series

Single-acting, self-aligning thrust bearing, leveling washer. 1100-U Series

Double-acting, self-aligning thrust bearing, leveling washers 2100-U Series

OPERATING at a speed of 6,000 r. p. m., the generator bearings of the Harley-Davidson Motor Cycle must obviously be reliable and smooth running.

In selecting bearings for this purpose, Harley-Davidson engineers recognized five outstanding advantages of Strom Ball Bearings over plain bearings:

1 A permanent and *uniform air gap between armature and coils* because the wear of Strom Ball Bearings is negligible.

2 *Minimum lubrication and elimination of oil leakage*, thus reducing maintenance costs and preventing insulation troubles.

3 *Marked reduction of friction*, thereby reducing and equalizing both starting and running resistance.

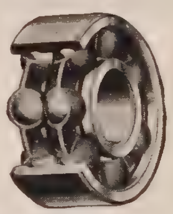
4 *More compact design* due to small bearing space required.

5 By taking end thrust as well as radial load *end motion of rotor and vibration are reduced.*

For the same reasons, manufacturers of many other types of electric motors are using Strom Ball Bearings.

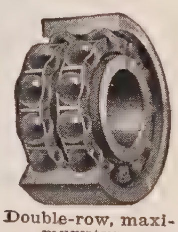
There's a Strom of the right type and size to fit your needs exactly. Our engineers welcome inquiries on any bearing problem. Write for further information.

Single-row, deep-groove type, radial bearing



Double-row, deep-groove, radial bearing bronze retainer

Angular contact bearing, combination radial and thrust

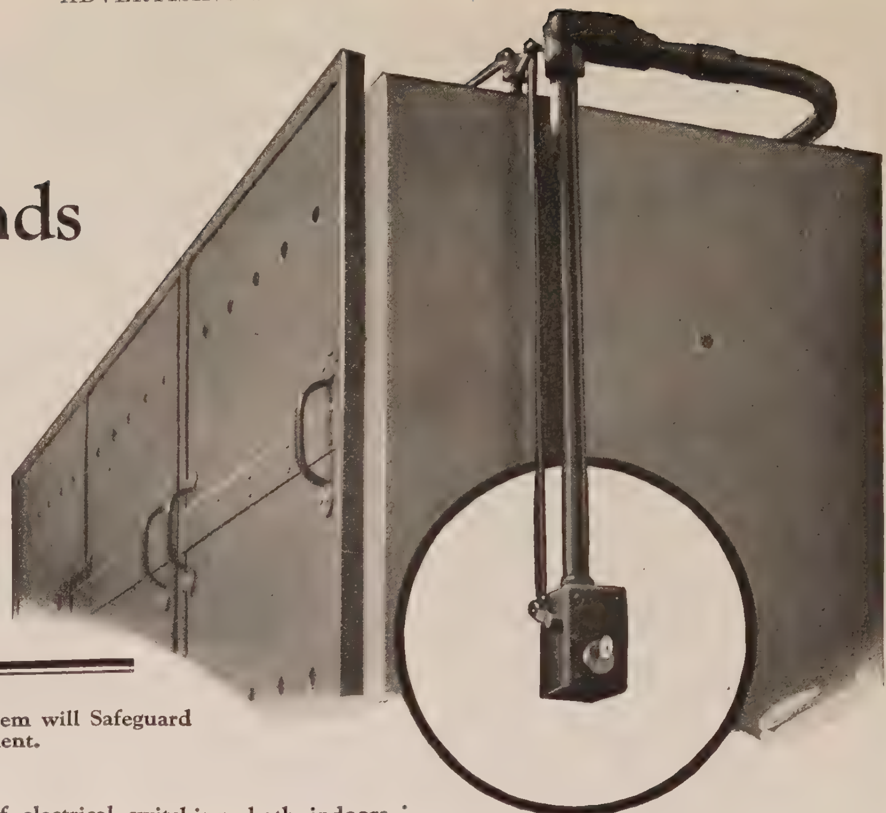


Double-row, maximum type, radial bearing

Strom BALL BEARINGS

STROM BALL BEARING MFG. CO.
4595 Palmer Street, Chicago, Ill.

Safety Depends On This Interlocking System



This fool-proof and positive device has become a necessity.

The ROBINSON Interlocking System will Safeguard and Protect your men and equipment.

It will mean:

1. Complete interlocking of electrical switching—both indoors and outdoors.
2. A disconnecting fuse or switch cannot be operated while current is flowing through it, when the ROBINSON Interlocking System stands guard.
3. Not only personnel protection is afforded but also protection to

   Oil Circuit Breakers
   Reactors
   Transformers
   Disconnecting Switches

No extensive changes in existing bus structures are required to install the Interlocks.

Our new bulletin 105-29-B gives full particulars.

May we send you a copy?

Switch Interlock B-986

CHAS. CORY & SON Inc.

183 Varick Street, New York City

Philadelphia: The Bourse
Boston: 110 High Street
San Francisco: 11 Mission Street
Seattle: 515 Hoge Building
New Orleans: 826 Barrone Street
Chicago
Detroit

"The World's Largest Manufacturers of Signaling, Communicating and Lighting Equipment."

Cory Service

Kuhlman Transformers

are backed by eager service

Kuhlman Transformer Installation at Detroit Copper and Brass Rolling Mills, handling wire and rod mills. Mr. G. S. Van Norman, Electrical Engineer.

THE Kuhlman Electric Company has manufactured transformers only, since 1893. Through these years of experience we have found that one of the most appreciated factors in our relations with customers is the prompt service that we give.

Our energies are directed to two things:

(1) Building a mighty good transformer quickly, and

(2) Taking care of your service needs within 24 to 48 hours, should you call on us.

ASK FOR BULLETIN 310.

KUHLMAN ELECTRIC COMPANY

Manufacturers of Power, Distribution and Street Lighting Transformers

BAY CITY - - - MICHIGAN

KUHLMAN TRANSFORMERS

There is nothing new in our stand on

I-T-E Air Break *vs.* Oil

600 volts or less

ON DECEMBER 1st, 1902, we published Bulletin No. 3 entitled, "I-T-E Circuit Breakers for Alternating Service." Just think a minute! That was over twenty years ago.

Hundreds of successful installations prove that we were R-I-T-E then. We unhesitatingly say we are R-I-T-E now.

The larger the size of the unit the greater the advantages of the I-T-E AIR BREAK over Oil Break, in *simplicity, reliability* and *effectiveness*, with the further incidental advantage of *lower first cost and negligible maintenance expense.*

More advantages gained by using
I-T-E AIR BREAK

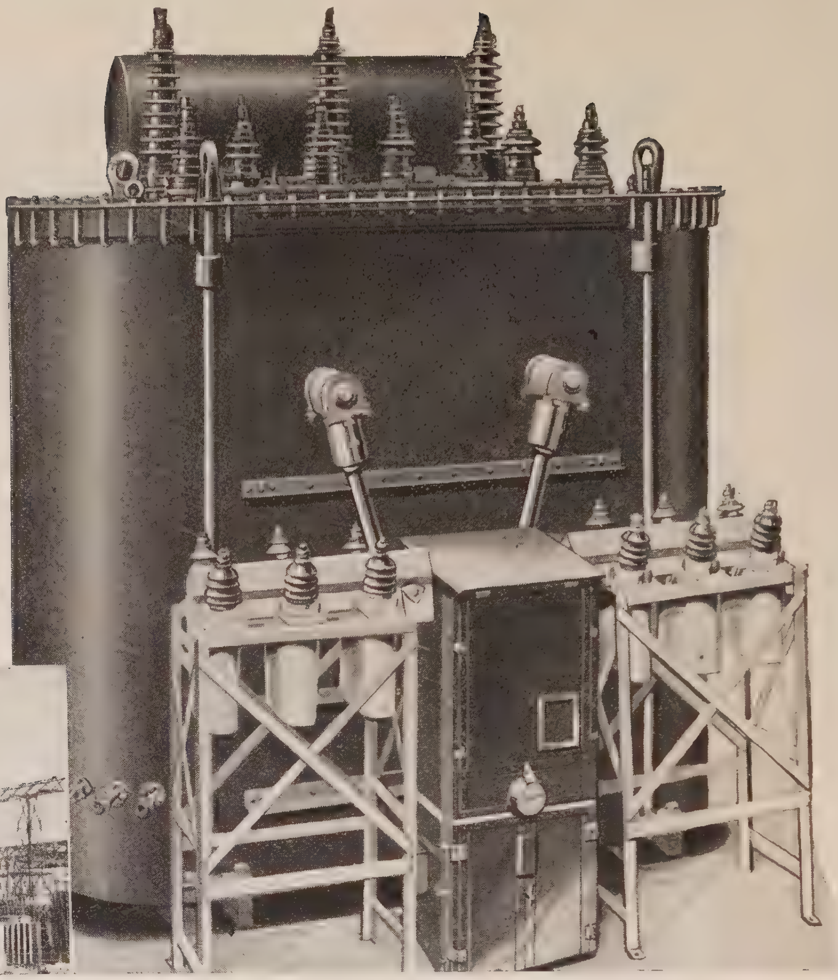
1—Protection without complication—all parts visible and accessible.
2—No oil—to leak, carbonize, burn or explode—just air.
3—No cells—nothing to be imprisoned—just a faithful and efficient servant.
4—No tanks to conceal anything—or the lack of it.
5—Inherent simplicity — with resulting low cost of installation and maintenance.

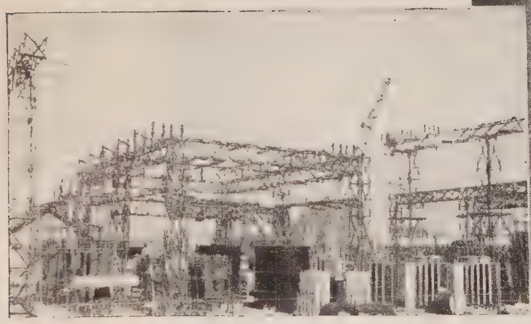
THE CUTTER COMPANY
ESTABLISHED 1888—PHILADELPHIA
1829 HAMILTON STREET

CUTTER

U-RE-LITE I-T-E CIRCUIT BREAKERS

1





Remote Voltage Control for 80,000 Kv-a.

The regulation of voltage at a distant point of a transmission line by controlling the ratio of the step-up transformers under load at another point remote from both the line and the transformers has been accomplished in this installation at the Chester Station of the Philadelphia Electric Company.

Four three-phase, 20,000-kv-a. General Electric power units are equipped with motor-operated tap-changing devices to obtain a 12% range in voltage on the 66,000-volt lines without dropping any part of the load. The push-button controls are located at an indoor switchboard 2000 ft. from the transformers, where indicating devices show the voltage at a point on the lines 7 miles distant. The voltage of the local load on the low-voltage bus feeding the transformers may thus be controlled independently of the transmission voltage.

This is the first installation of its kind in the world.

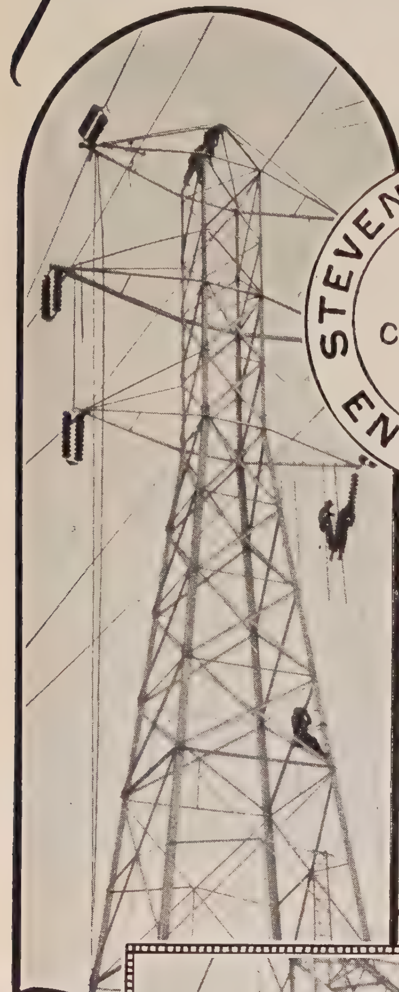
The innovations of Industry are its best dividends and the real measure of its progress. The complete transformer laboratories of the General Electric Company, together with its extensive experience—both made possible by the confidence of the public—must make constant return to that public in new and permanent things.

17DH-7

GENERAL ELECTRIC

GENERAL ELECTRIC COMPANY, SCHENECTADY, N. Y., SALES OFFICES IN ALL LARGE CITIES

The Ohio River Edison Company completes the First installation of the NEW LOCKE HEWLETT insulators



To Stevens & Wood, Inc., New York, goes the credit for the first installation of the New Locke Hewlett insulators. Quick to realize the importance of so valuable a development, the Stevens & Wood engineers ordered comparative tests made with other types. Every known method for determining ultimate performance under operating conditions was employed under the direction of research engineers in the foremost electrical laboratory of the country. The electrical and mechanical characteristics far exceeded the values ever before developed in a Hewlett insulator, and the decision was made to install the New Locke Hewletts on the new line of the Ohio River Edison Company, then under construction.

STEVENS & WOOD Inc.
DESIGN
FINANCE
CONSTRUCT
MANAGE
ENGINEERS

This is a 132,000-volt line, forty miles in length, extending from the generating station at Toronto, Ohio, to the Boardman Substation four miles south of Youngstown. At this point the energy is stepped down to 66,000 volts and is connected with the properties of the Pennsylvania-Ohio Power and Light Company, the Pennsylvania-Ohio Electric Company, the Shenango Valley Electric Company and other subsidiaries of the Republic Railway and Light group.

The New Locke Hewletts are also employed in suspension at Toronto and Boardman for all main busses and taps. This line is now in operation, and operating companies are referred to Stevens & Wood for information covering the results so far obtained.

LINE DATA

196 steel towers—span length, 1070 feet.

Towers, 75 feet high at lower cross arm with 10-foot and 20-foot extensions as needed.

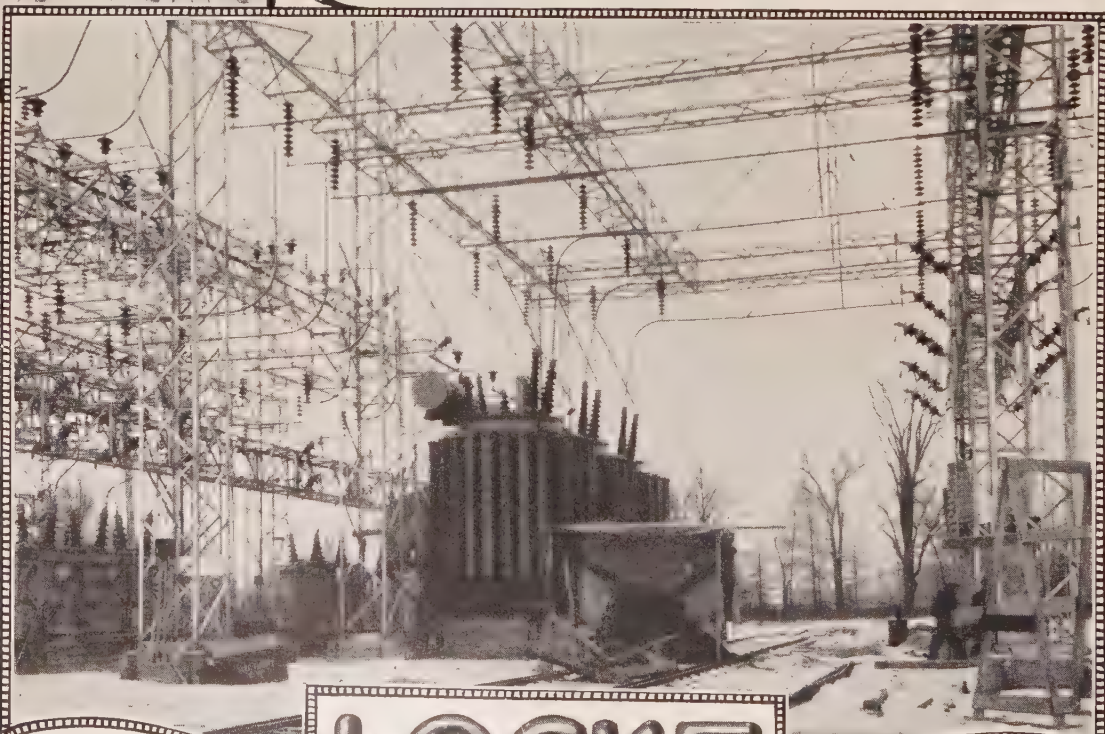
Vertical spacing between cross arms, 13 feet.

Top and bottom cross arms, 23 feet 9 inches long. Middle cross arm, 28 feet 9 inches long—giving a 2½-foot offset to prevent insulator strings touching under heavy sleet conditions.

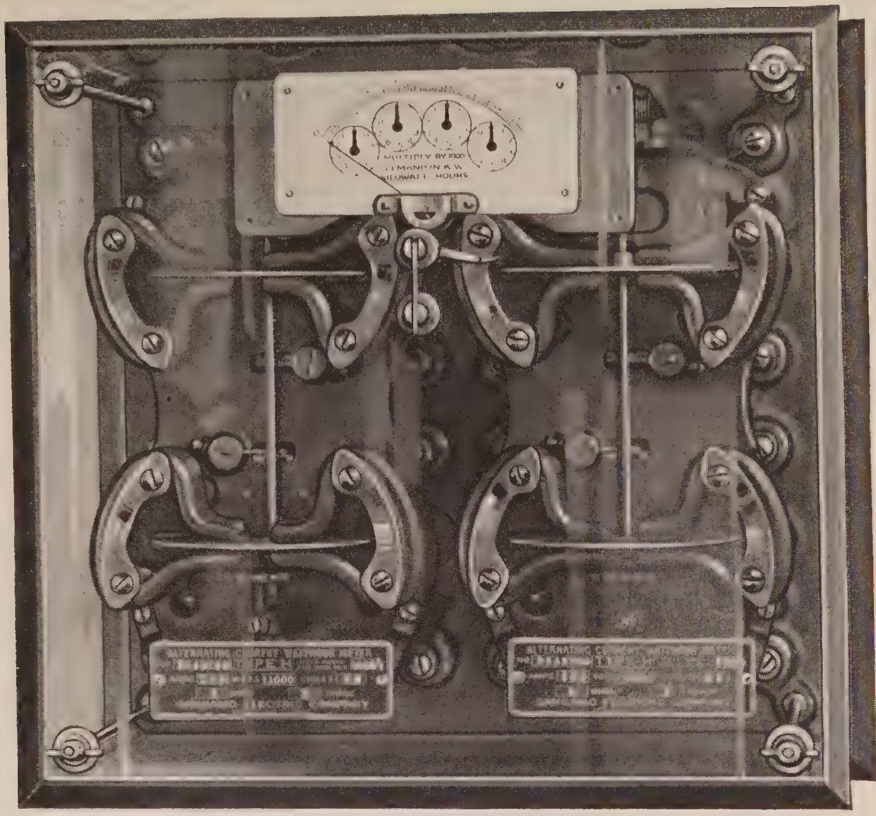
Size of cable 300,000 circ-mils, 19-strand copper.

Locke units used in suspension, 9; Locke units used in strain position, 10.

LOCKE INSULATOR CORPORATION
BALTIMORE, MARYLAND
Factories at Victor, N. Y. and Baltimore, Md.



LOCKE
PORCELAIN



Sangamo double polyphase meter equipped with differentially geared maximum-demand register. Used for summation of energy consumption and for determining total maximum demand of two circuits

SANGAMO

Double Polyphase Meter

for energy summation or load analysis

THE Sangamo switchboard type double polyphase meter was originally designed to enable a prominent central station to measure the interchange of power in a transmission circuit where the available switchboard space was limited. Consisting of two vertical polyphase meters on a single base, the design is readily adaptable to additional fundamental uses—measurement of power in separate circuits or for the determination of the energy and reactive components in a single circuit.

Each polyphase element may be fitted with a standard register for measurement of energy in separate circuits and, if desired, the registers may be equipped with detents thus obtaining measurement in and out on interchange of power.

For purposes of load analysis, by comparison of readings of energy and reactive components, one of the polyphase elements can be internally connected to measure reactive component. This does away with the necessity of complicated external connections and permits the use of the standard potential element.

In any of these arrangements the type HMP demand attachment can be substituted for the standard register thus indicating the maximum demand in separate circuits, or the energy and reactive component demands in the same circuit.

The polyphase elements are so mounted that a single differential register of the type used on Sangamo horizontal polyphase meters may be installed. This permits the summation of energy in two separate circuits on a single register. Moreover, the register may be fitted with a type HMP demand attachment for the purpose of obtaining the maximum demand of the two circuits which could not be obtained with separate meters.

When separate circuits are being metered by the polyphase elements, they need not be of the same rating in volts, amperes, or cycles.

The development of this meter is additional evidence of the progressive Sangamo policy in the contribution of new and useful metering devices for the central station industry.

SANGAMO

SANGAMO ELECTRIC COMPANY
SPRINGFIELD, ILLINOIS

New York Boston Chicago Birmingham San Francisco Los Angeles

1023-11

SANGAMO METERS
FOR EVERY ELECTRICAL NEED

Why Not Face the Facts,
Mr. Motor Manufacturer?

YOU KNOW that the application of high-grade ball bearings in your fractional hp. motors will make them BETTER motors—

BETTER IN EVERY RESPECT which makes for saleability and serviceability and customer satisfaction.

YOU KNOW that the trade is waiting for the "trouble-proof" motor, the "neglect-proof" motor. And—

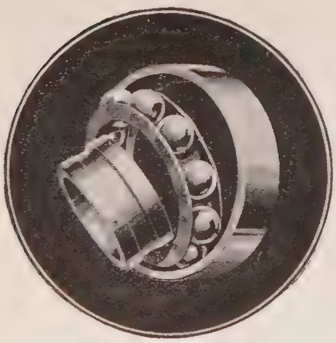
YOU KNOW that ball bearings correct the greatest source of trouble in motors today—neglected or improper lubrication. Furthermore—

YOU KNOW that a ball bearing motor is a more efficient motor, electrically and mechanically—uses less current—starts more easily—lasts longer—costs less to run and to maintain—sells more easily.

Why not face these facts fairly and squarely and—in the face of a very slight increase in production cost—give your motors this final refinement which will make them practically "neglect-proof" and "trouble-proof"?

You will come to it ultimately—the trade and the public will demand it. It is only a question of time.

Why not put yourself among the leaders?



"NORMA"
Open Type
PRECISION
BALL BEARINGS

Motor manufacturers who realize the dollars-and-cents value of distinct improvements are already using "***Norma***" Precision Ball Bearings—in ever-increasing quantities. They have convinced themselves, by most exacting tests in factory and field, that "***Norma***" Precision Ball Bearings—the preeminent speed bearings—do make good fractional hp. motors better. The same sales advantages are awaiting your decision.

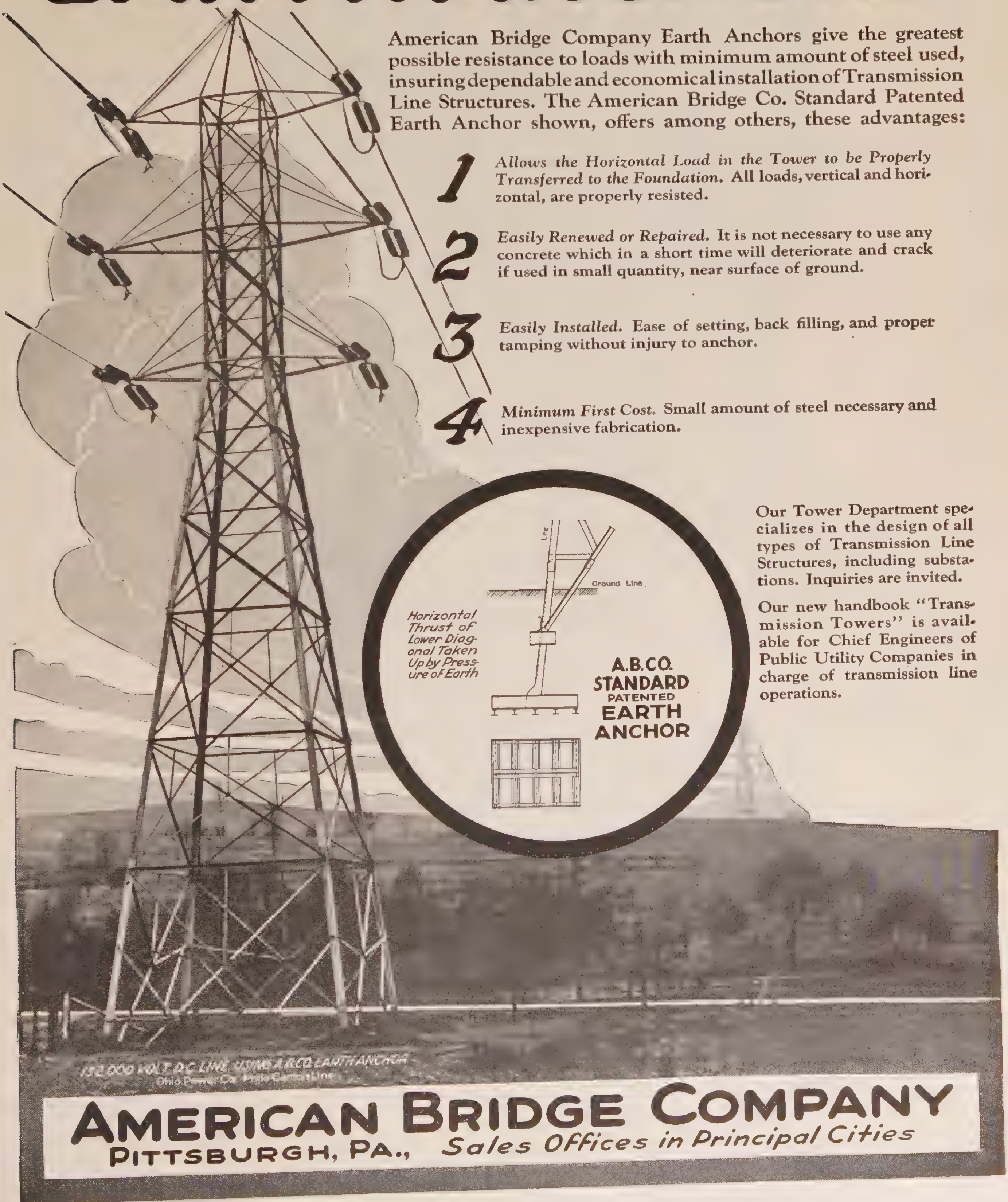
"NORMA"
Closed Type
PRECISION
BALL BEARINGS

NORMA-HOFFMANN BEARINGS CORPORATION

Stamford—Connecticut

PRECISION BALL, ROLLER AND THRUST BEARINGS

Advantages of Efficiently Designed EARTH ANCHORS



American Bridge Company Earth Anchors give the greatest possible resistance to loads with minimum amount of steel used, insuring dependable and economical installation of Transmission Line Structures. The American Bridge Co. Standard Patented Earth Anchor shown, offers among others, these advantages:

1. *Allows the Horizontal Load in the Tower to be Properly Transferred to the Foundation.* All loads, vertical and horizontal, are properly resisted.

2. *Easily Renewed or Repaired.* It is not necessary to use any concrete which in a short time will deteriorate and crack if used in small quantity, near surface of ground.

3. *Easily Installed.* Ease of setting, back filling, and proper tamping without injury to anchor.

4. *Minimum First Cost.* Small amount of steel necessary and inexpensive fabrication.

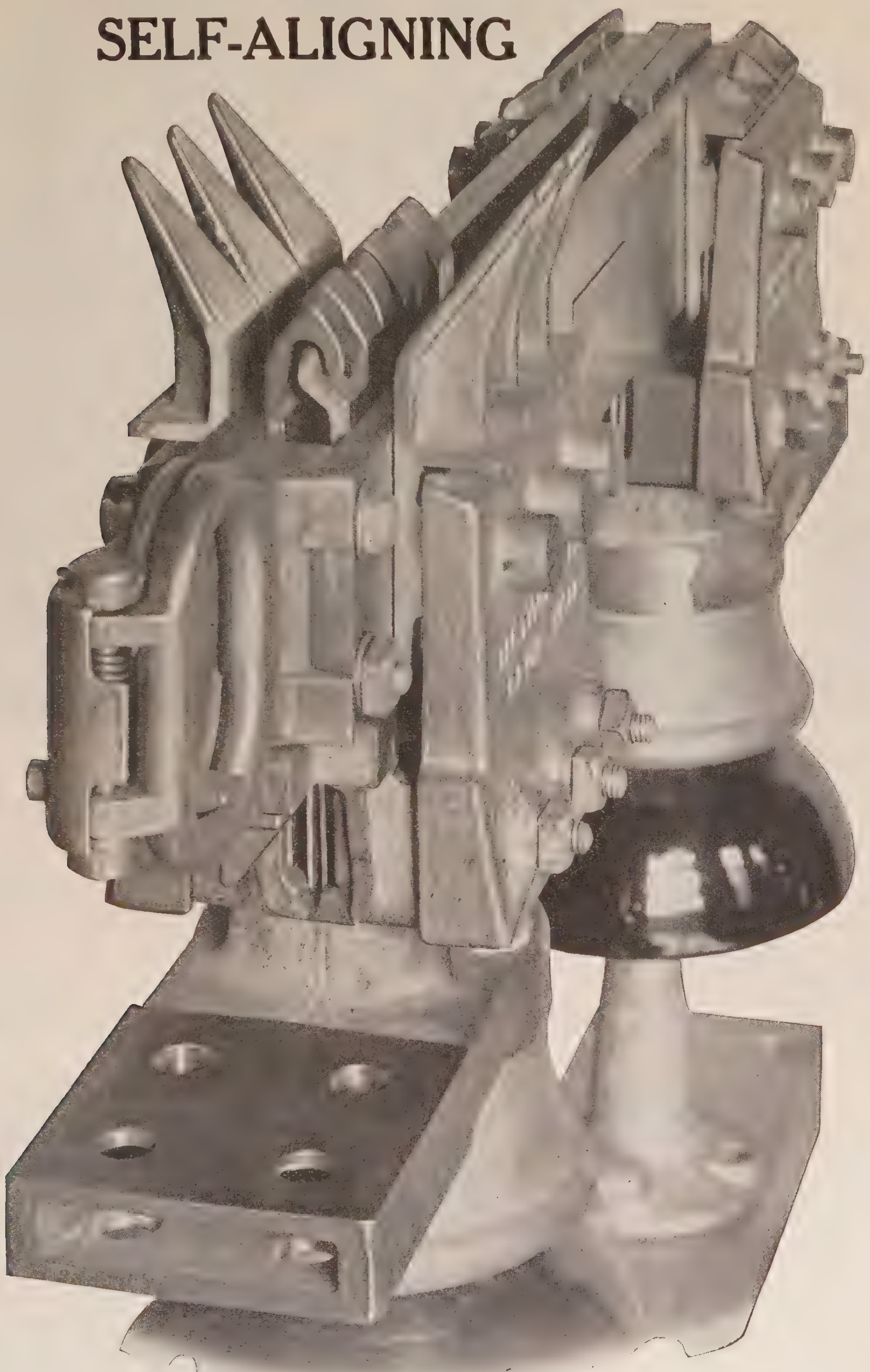
Our Tower Department specializes in the design of all types of Transmission Line Structures, including substations. Inquiries are invited.

Our new handbook "Transmission Towers" is available for Chief Engineers of Public Utility Companies in charge of transmission line operations.

AMERICAN BRIDGE COMPANY

PITTSBURGH, PA., *Sales Offices in Principal Cities*

"FULL FLOATING" SELF-ALIGNING

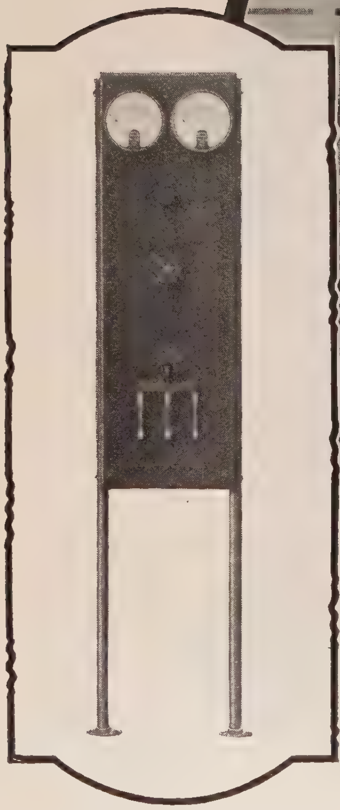


5815 Third St., San Francisco

50 Church St., New York.
Pioneer Bldg., St. Paul.
Interurban Bldg., Dallas.
Hoge Bldg., Seattle.
Ferguson Bldg., Los Angeles.
Symes Bldg., Denver.

PACIFIC ELECTRIC MFG. CO.
SAN FRANCISCO — CALIFORNIA

Generating Station Control Desk



Type JD Exciter Panel

A Wide Range—Well Covered

FROM the smallest to the largest switchboards, from the simplest of single panels to complicated control desks, supervisory control and the automatic operation of stations, Westinghouse switching equipment fills every need.

Specialists—each an authority on a certain type of switching apparatus—keep Westinghouse well in advance of the demands of the electrical industry. Their skill is at your service. Write our nearest district office for the solution of your switching problems.

Westinghouse Electric & Manufacturing Company
East Pittsburgh Pennsylvania
Sales Offices in All Principal Cities of the United States and Foreign Countries

Westinghouse

X-80651

The New G & W Vault Unit

~An up-to-the-minute application of the "G&W Idea" to transformer Vaults~

It provides---

An oil submerged double throw disconnect operated from outside the vault.

Disconnects between both cables and oil throw over.

Disconnects between each transformer lead and the vault unit.

With it---

Load may be carried by either cable with oil tank dropped and oil throw over entirely dead. The two cables may be tied together as an emergency tie between circuits. This operation is also independent of oil throw over. Light may be taken from any phase as desired. Power may be operated open delta. In fact every operation needed on the primary side of a vault, is provided for in this one compact unit.

Load Shifting

Transformer load can be shifted from main to emergency feed by throwing oil disconnect. Load can be killed by throwing oil disconnect.

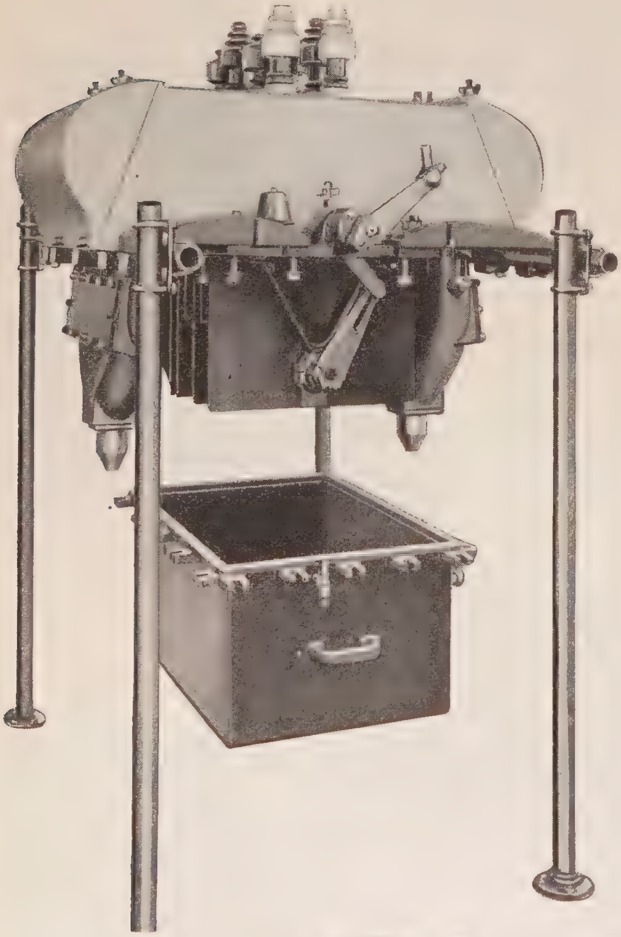
The New G & W Vault Unit

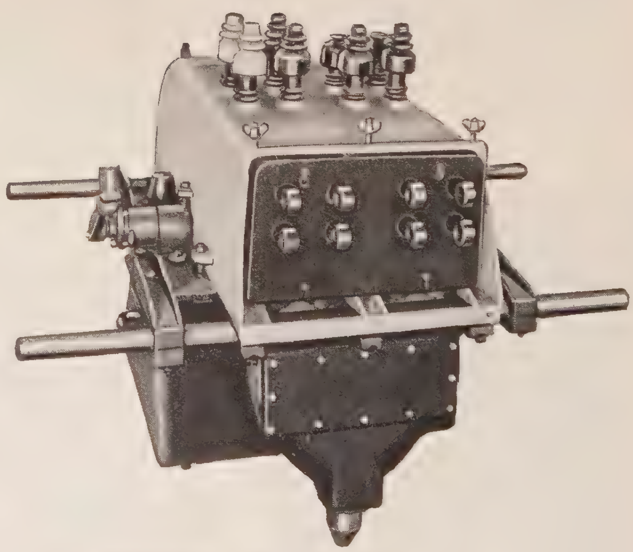
enables a great saving in space, labor, and material. It means strict economy. Maximum continuity of service is realized. In addition you have complete safety—there being no exposed live metal parts.

The unit is offered for mounting into your bus structure, or we will be glad to quote unit structure fully equipped with bus, cutouts, etc.—a vault complete except for transformers and walls.

Write for folder

Folder VA4 giving full details sent on request.





G & W ELECTRIC SPECIALTY CO.
7780 DANTE AVE. CHICAGO, ILL.

Your motor horses—
are they big ones or little ones?

Wagner Products

MOTORS
Split-phase—Induction
Repulsion—Induction

Pow-R-full Squirrel-cage
Pow-R-full Starterless
Slip-ring Induction

Fynn-Weichsel

TRANSFORMERS
Distribution
Power

FANS
Desk, Wall and
Ceiling Types
AC and DC

AUTOMOTIVE
Starting—Lighting
Ignition

Official service representatives for Lockheed four-wheel hydraulic brakes

1220-2

YOU are interested in motors for the sake of the work you get out of them. Off-hand you would say (wouldn't you?) that you ought to get as much work out of one 15 hp. motor as another 15 hp. motor.

But you would be wrong.

A 15 hp. motor is a motor guaranteed to carry a 15 hp. load *continuously* with no more than 40° rise in temperature.

But the amount of work you get out of a motor depends upon *six* points, of which the rated horsepower is only one, and often not by any means the most important one. The other five are:

1. The amount of load it can start without blowing the fuses.

2. The size of the overload it can carry momentarily without stalling, burning out or blowing the fuses.

3. The amount of magnetizing current it demands.

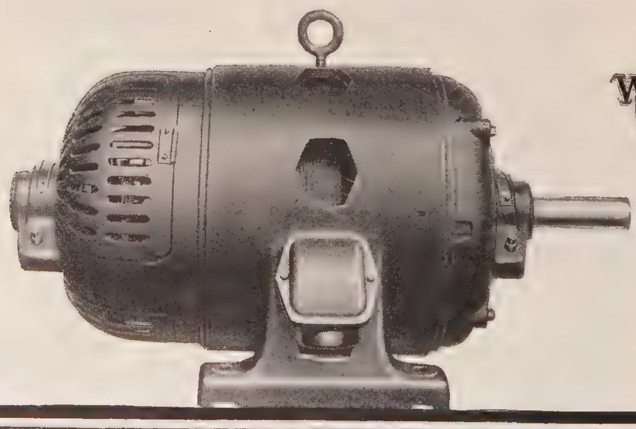
4. The effect it has on voltage, and hence on the performance of the other motors in your shop.

5. Its ability to hold its speed under unfavorable conditions.

You can buy motors that don't cost much in terms of rated horsepower, but *will they do the work?*

The FYNN-WEICHSEL MOTOR costs more per rated horsepower, but it gives you more motor—more work—for your money.

WAGNER ELECTRIC CORPORATION
6400 Plymouth Avenue, *St. Louis, Mo.*



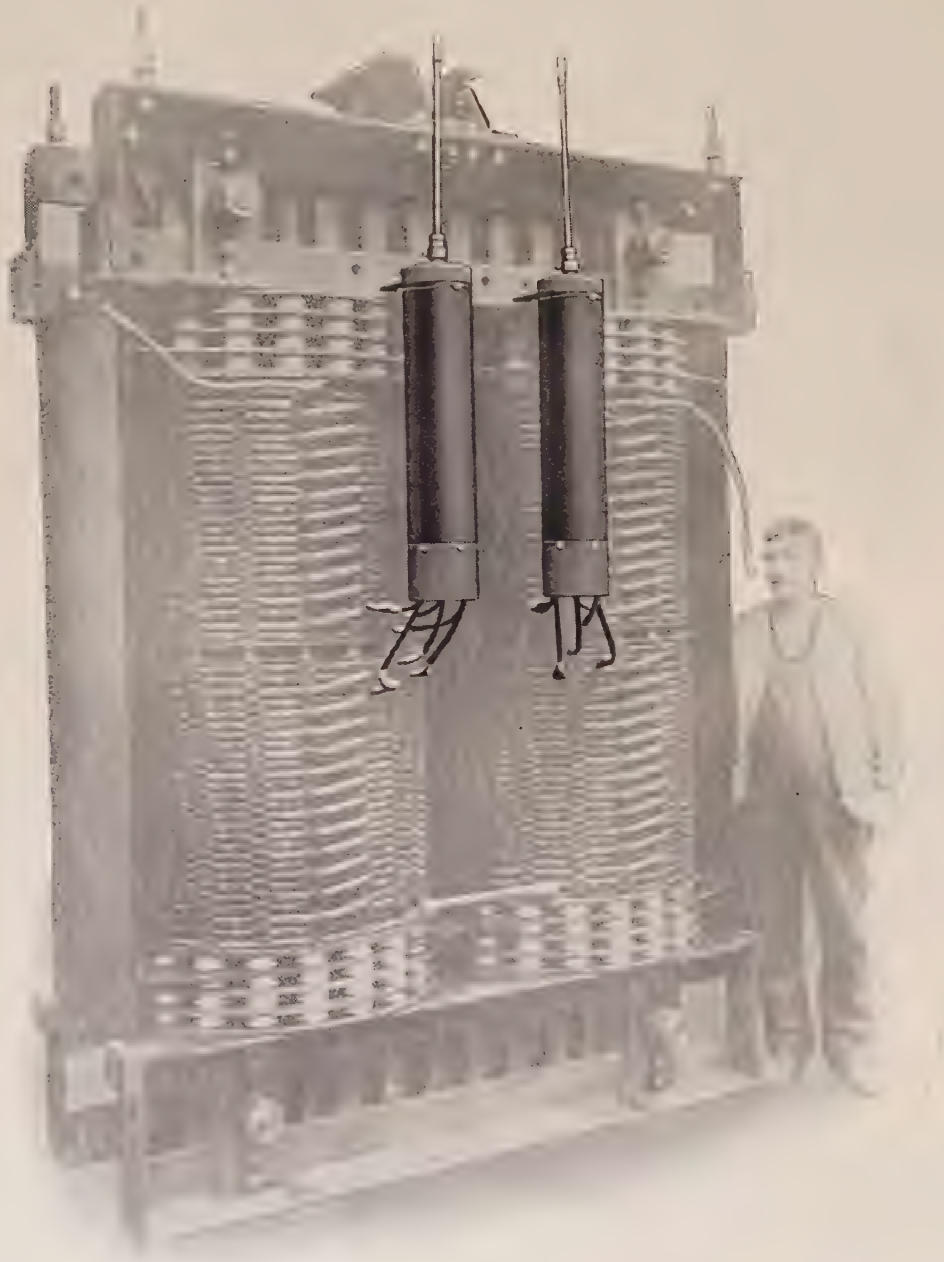
Wagner Quality

Fynn-Weichsel

The motor that corrects power-factor

FERRANTI

EXTERNALLY OPERATED OIL IMMERSED TAP SWITCHES



Tap Switches Fitted on a Single Phase, 4,000 K. V. A. Transformer

FERRANTI, LTD., Hollinwood, Lancashire ENGLAND

FERRANTI METER and TRANSFORMER MFG. CO., LIMITED
TORONTO CANADA

Seal Beach Power Station, Los Angeles Gas and Electric Corporation

Dwight P. Robinson & Company, Inc., Engineers and Constructors.

FRANKLIN BUS-SUPPORTS IN THE SEAL BEACH STATION WITHSTOOD TERRIBLY SEVERE TESTS

Yet *every* bus-support leaving our plant and bearing our name must stand these same tests. In addition, there are the most minute inspections, timed to uncover any hidden flaw.

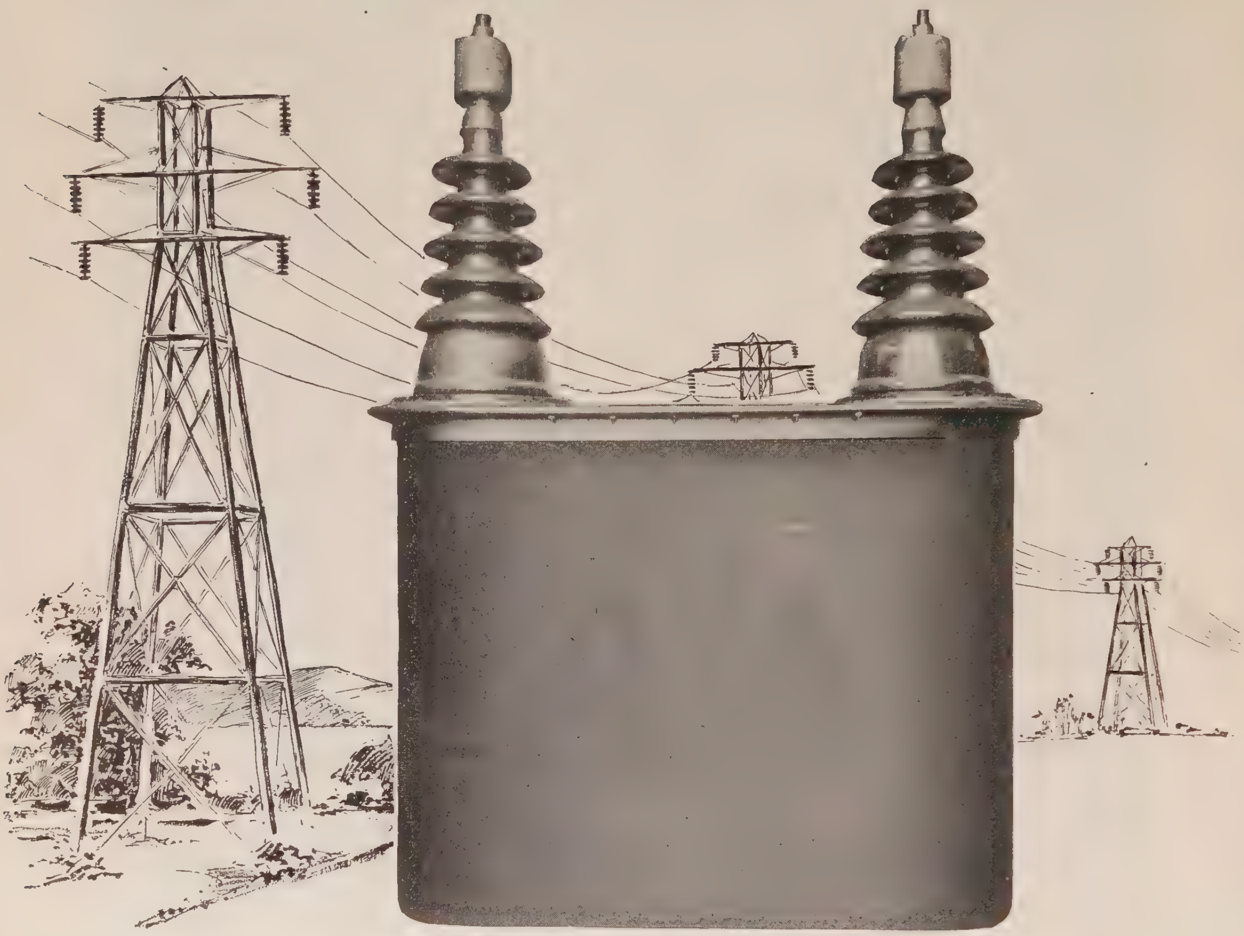
Take for instance, just after we die cast the collar on the porcelain—the dies are opened and a rigid inspection of this work is made, which is an opportunity not afforded in any other method of hardware attachment. Any imperfection at this or any other stage of the manufacturing process means instant rejection of the bus-support, no matter how much work may have been done on it.

These tests, inspection and rejection are the reasons for Franklin Equipment costing a little more—but we feel that you will gladly pay a little extra for the increased factor of safety which they give.

ELECTRICAL DEVELOPMENT AND MACHINE CO.
PHILADELPHIA

FRANKLIN
POWER EQUIPMENT

American



for high Voltage Testing

American 300,000 Volt 60 cycle testing transformer

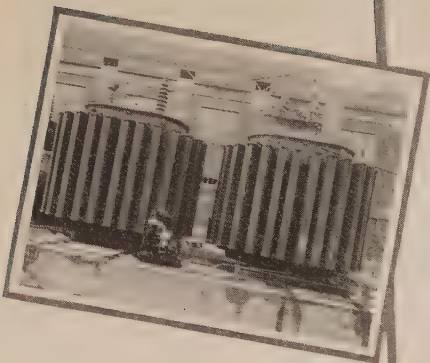
The increasing use of high voltages for transmission purposes has made it necessary to build much higher voltage testing transformers than formerly were needed.

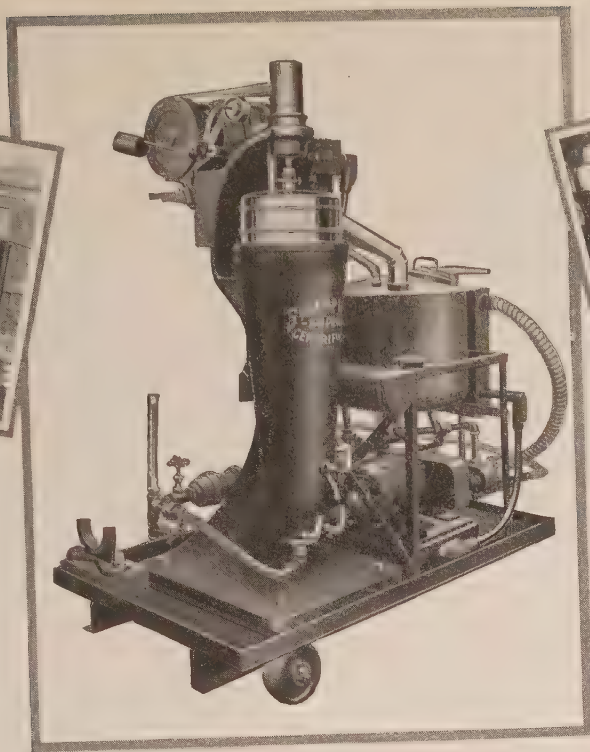
Here is a 300,000 volt, 60 cy. testing transformer with the center of the high tension grounded. This transformer is provided with a voltmeter coil closely associated with the high tension winding to indicate the high tension voltages. It is used in connection with a voltage regulator so as to obtain a gradual increase in voltage on the high tension side.

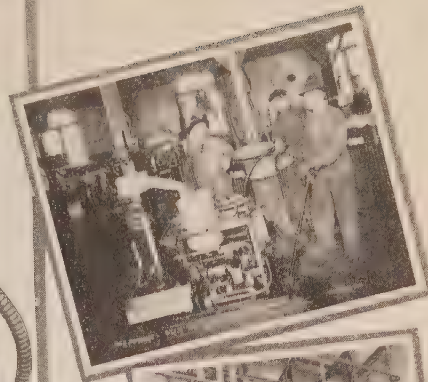
If you have a transformer problem American Transformer Company's engineering staff can help you. Send for bulletin 1025 which illustrates some American units.

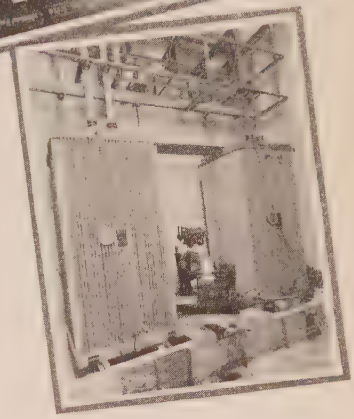
AMERICAN TRANSFORMER CO.
176 EMMET ST., NEWARK, N. J.

Transformers









There is no other equipment so effective and so easy to operate, nor so easy to clean and reassemble, as the Sharples Portable Super Centrifuge. Its economical operation justifies *frequent* reconditioning of all oils used for insulating purposes—even to the oil used in pole transformers.

In large power plants all over the country the Sharples Portable Super Centrifuge has proven its superiority over other oil purifiers for maintaining dielectric strength at the lowest possible operating costs.

Removal of moisture and sludges from transformer oil by the Sharples Portable Super Centrifuge is always dependable and the results are always uniform.

The Super Centrifuge used with the Sharples chemical treatment is the safe, positive method of restoring switch oils to meet their original specifications.

Mail coupon today for valuable information on the Sharples Portable Unit and the new Sharples Switch and Transformer Oil Process.

* * *

When you think of Centrifugal Force —say Sharples.

THE SHARPLES SPECIALTY COMPANY
2324 Westmoreland Street
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Foreign Offices: London - Paris - Tokio
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Be sure it's a
SHARPLES

HAVE YOUR SECRETARY FILL THIS OUT AND MAIL

SHARPLES SPECIALTY CO.
23rd and Westmoreland Sts., Philadelphia, Pa.
Without obligation on my part, send complete data on:

Name__________
Company__________
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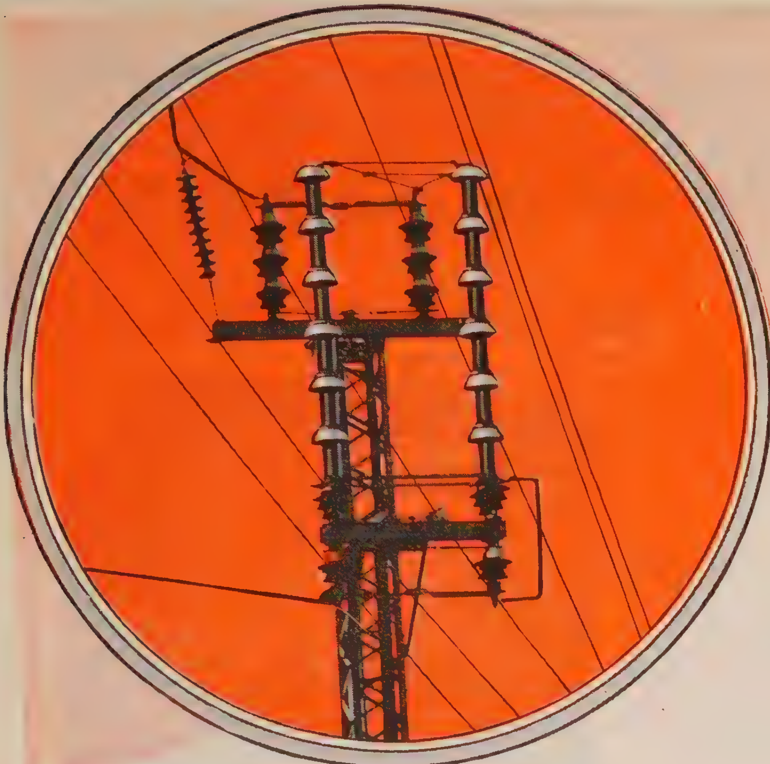
34



Six Type No. 670, 22,000 volt condenser units bolted together in series for coupling telephone systems to 132,000 volt transmission line.

Condenser Coupling *for* Power Line Telephony

Condenser coupling for power line telephony carrier current systems affords a reliable and efficient method of conveying telephone conversation *direct* to the power line.

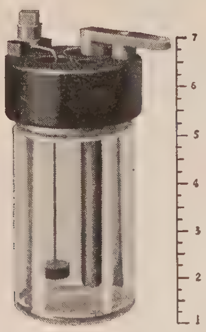
Condenser coupling does not require the difficult and expensive changes to power lines and tower structures which were necessary to effect an ideal antenna arrangement. This coupling system operates with a minimum radiation of the telephone energy to other power lines.

Dubilier type 670 condenser units, designed for this purpose, can be arranged in series—multiple combination for any line voltage or coupling capacity.

Type No. 670 Condenser built in capacities of .001 to .003 Mfd. for line voltage of 22,000 volts, 60 cycles AC.

For particulars address
Dubilier Condenser & Radio Corporation
4377 Bronx Boulevard, New York City

Dubilier



Balkite Type C-3 Industrial Rectifier Cell

The type C-3 Balkite rectifier cell has been developed to meet the needs of industrial and communication service. It can be used to charge batteries or to furnish D. C. without the use of batteries. It can be used in connection with proper transformers on A.C. circuits of any commercial frequency.

This cell will carry currents of ¼ to ⅓ ampere continuously and 2 to 3 amp. intermittently. Up to 7 cells of lead battery can be charged with it or up to 30 volts D. C. furnished without battery but with the proper filter circuit. Other sizes are also available to carry other currents and higher voltages can be handled by connecting cells in series.

We will gladly furnish complete information and will cooperate in working out specific applications to your production processes.

The Balkite rectifier is already the standard on 20 railroads, and is the leader in the field of charging radio batteries.

FANSTEEL

Balkite Rectifiers

FANSTEEL PRODUCTS COMPANY, INC.
NORTH CHICAGO, ILL.

Savings by Squaring the Circle with

WESTON RECTANGULARS

ENGINEERS planning switchboard extensions or new switchboard installations are faced with the problem of limited space. Weston has made it easy to overcome this difficulty by their new line of Rectangular Instruments.

To meet these conditions Weston has placed its standard electrical instrument mechanism in a new case. Because of the Rectangular shape of tnis new case (6″x 5¾″) great savings in switchboard space are made possible and the long scales of the famous round pattern are retained.

Better scale illumination, bolder arcs and figures—an instrument with a quickly removable case and ease of installation—a new lay-out worthy of investigation and study.

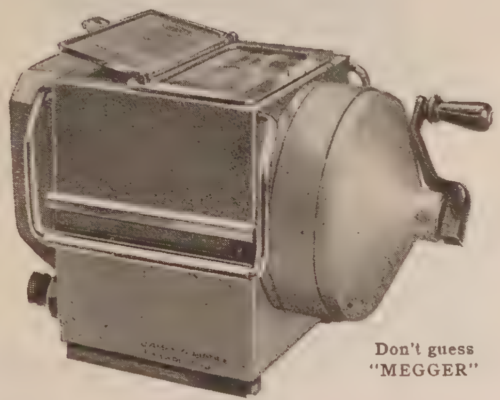
This new line is complete consisting of Alternating Current Ammeters, Voltmeters, Wattmeters, Frequency Meters, Power Factor Meters, Triplex Ammeters; and Direct Current Voltmeters and Ammeters.

For Further Information Address

Weston Electrical Instrument Corporation
48 Weston Avenue, Newark, N. J.

STANDARD THE WORLD OVER
WESTON
Pioneers since 1888

No one who ought to "MEGGER" *need hesitate on account of cost*



Don't guess "MEGGER"

"Super-Meg" Insulation Tester

Registered "Megger" Trade Mark

With constant-pressure 500 volt d.c. generator; scale range 0 to 100 megohms. Size: 5 1/8x8 5/8x6 1/4 in. high. Weight, 7 1/4 lb.

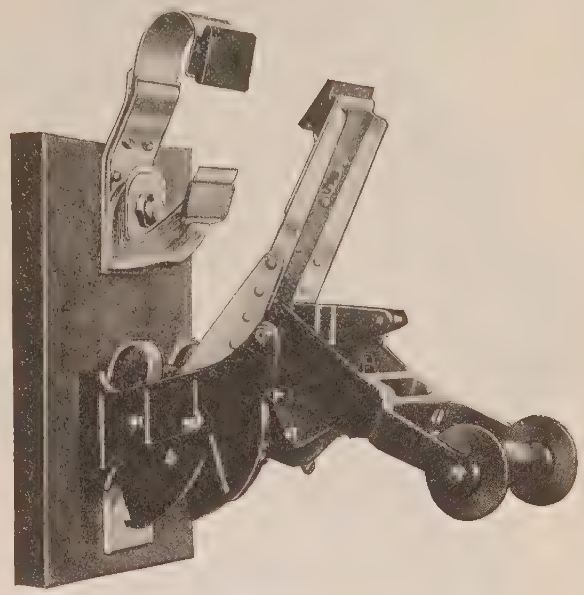
THE "Super-Meg" has been developed specially for smaller Central Stations, Manufacturing Plants and for Electrical Engineers and Inspectors who have needed a small size, low-cost device for "Meggering" electrical equipment.

The "Super-Meg" is similar to the "Megger" Testing Set in that it has a constant-pressure d. c. generator, and therefore can be used for testing electrical apparatus and cables having electrostatic capacity. Anybody can use it,—simply connect the two binding posts—one to the conductor of machine or circuit and the other to ground (or to the other conductor), turn the crank at about 120 r. p. m. and read insulation resistance directly on the scale. The field of usefulness of the "Super-Meg" is governed largely by its range of 0 to 100 megohms.

Our Pocket Manual 1060-J: "Concerning Insulation Testing," contains valuable data on the subject, describes the "Super-Meg" and gives full directions for its use. Write for a copy.

James G. Biddle
ELECTRICAL INSTRUMENTS
1211-13 Arch Street - - - Philadelphia

YOU CAN'T CLOSE THIS BREAKER IF AN OVERLOAD EXISTS



The reason why you can't close this

ROLLER-SMITH

FREE HANDLE CIRCUIT BREAKER

on an overload is that the handle is *entirely free* from the tripping mechanism and the breaker is, therefore,

NON-CLOSABLE ON OVERLOAD

The new ROLLER-SMITH Free Handle Breaker is now ready. It is the ideal answer to the ever present requirement of SAFETY.

Simplicity—the outstanding characteristic of all ROLLER-SMITH breakers—is something that will appeal to the electrical engineer who wants safe, sure and certain protection under any and all conditions.

New Supplement to Bulletin AE-530 is ready. Send for your copy. Use the coupon below.

"An experience of over 30 years is behind every Roller-Smith Product"

ROLLER-SMITH COMPANY
Electrical Measuring and Protective Apparatus

Main Office: 12 Park Place, NEW YORK

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Request for Supplement to Roller-Smith Bulletin AE-530

Name..........

Address..........

Company..........

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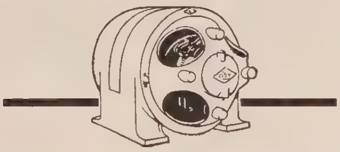
State..........

Which Bearing for Electric Motors?

Sleeve or Annular Ball?



THERE are many reasons which conclusively prove the general superiority of ball bearings over sleeve bearings for electric motors.

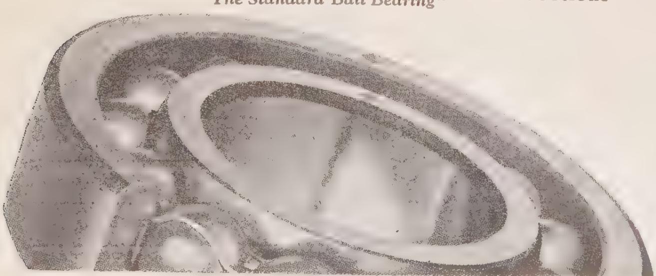
One is found in the all important subject of proper lubrication. Sleeve bearings require a large amount of oil which, because of the quantity needed has a tendency to leak out onto the windings. Furthermore their proper operation is dependent on a continuous supply of oil—necessitating almost daily attention to avoid burning, wearing, or seizing of the bearings.

On the other hand, annular ball bearings permit easy control of lubrication. A small charge of oil or grease can be effectively sealed where it will stay—properly lubricating for four to six months without attention.

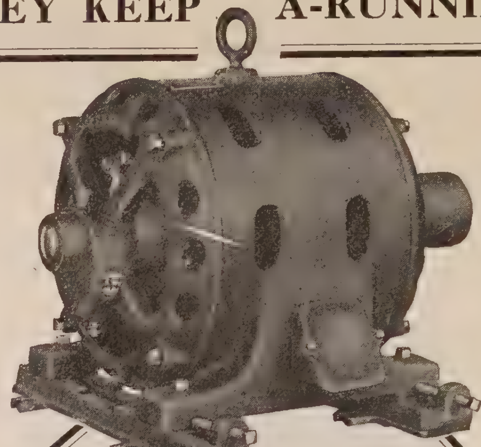
One great feature of Annular Ball Bearings for electric motor usage is this ability to operate for long periods with little attention. This together with the durability, ruggedness and quietness, so inherently a part of SRB Bearings, is responsible for their popular adoption by Electrical Engineers.

STANDARD STEEL AND BEARINGS INCORPORATED

Plainville "The Standard Ball Bearing" Connecticut



"THEY KEEP A-RUNNING"



7½ H. P. Century Repulsion-Start Induction Single Phase Motor

They Develop Heavy Starting Torque

The heavy starting torque developed by Century Repulsion-Start Induction Single Phase Motors renders them especially desirable for the operation of refrigerating machines, crushers, mixers, pumps, heat regulators, sewerage disposal equipment, garage air compressors and also other similar apparatus usually employing automatic or remote control.

The low starting current requirements of this motor—not in excess of 245% of full load current—permits the use of any standard single throw switch for starting. A fuse which will protect the motor while running and carrying its load, is usually of ample capacity for starting due to the low starting current and quick acceleration.

The new Century Wool-Yarn System of Lubrication can now be furnished in all Century RS Motors of fractional horse power sizes.

Built in all standard sizes from 1-8 to 40 horse power—temperature rise not more than 40 deg. Centigrade.

Send for Bulletin No. 29

Bulletin No. 29 describes all superior features of Century Repulsion-Start Induction Single Phase Motors—a copy will be mailed to you on request.

CENTURY ELECTRIC COMPANY

More than 23 years at St. Louis, Mo., U. S. A.

⅛ to 40 H.P. Century MOTORS ⅛ to 40 H.P.

2518

OLSEN TESTING MACHINES

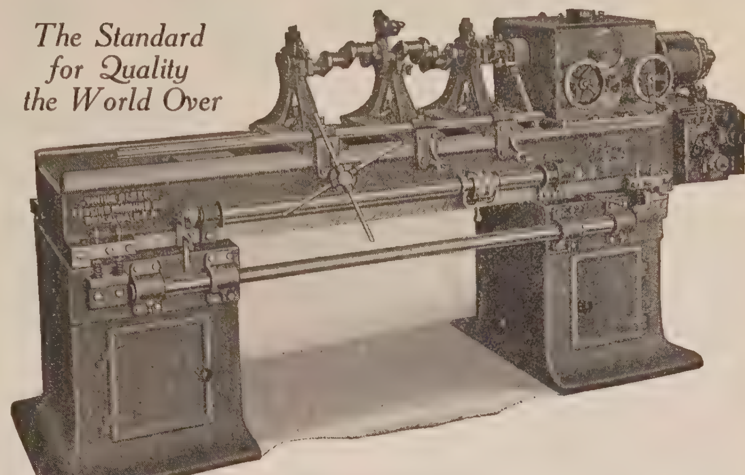
UNIVERSAL TESTING MACHINES for tension compression and transverse tests of all metals and materials.

HARDNESS TESTING MACHINES for Brinell Hardness tests of all material including sheet metal.

DUCTILITY TESTING MACHINES for determining drawing quality of sheet metal. CEMENT, CONCRETE, CHAIN, ANCHOR, WIRE, ROPE, OIL PAPER, CLOTH, and Rubber Testing Machines.

TORSION, IMPACT, REPEATED IMPACT, TOUGHNESS, ENDURANCE, WEAR, ALTERNATE STRESS and EFFICIENCY Testing Machines.

The Standard for Quality the World Over



OLSEN-CARWEN STATIC-DYNAMIC BALANCING MACHINES

Eliminate Vibration—Secure Perfect Balance with Speed and Economy

The Olsen-Carwen is made in many sizes and types to balance any rotating parts from the smallest to the largest rotor made. Now used by all the leading up-to-date automobile and motor manufacturers throughout the country.

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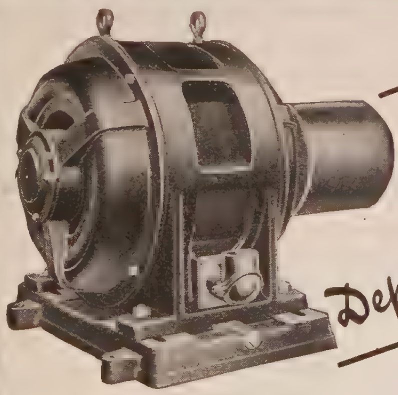
Foreign Representatives—*Messrs. R. S. Stokvis & Fils, Paris, France, Brussels, Belgium, Rotterdam and Amsterdam, Holland. Edw. G. Herbert, Ltd., Manchester, Eng. Andrews & George Company, Tokyo, Japan.*



Built for Dependability

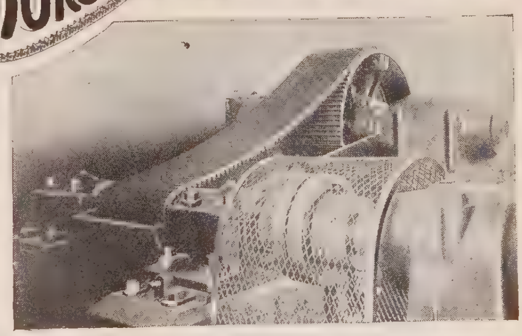
WHEN the **Electro Dynamic** Polyphase Induction motor was first conceived, it was our determination to produce a motor as dependable as human ingenuity and practical limitations would permit. A motor so well designed, electrically and mechanically, of such sturdy construction, of such expert workmanship, that it would be practically trouble-free and fool-proof.

Our engineers will be glad to explain to you the many distinctive features that mean absolute dependability and true economy.

ELECTRO DYNAMIC COMPANY
(Est. 1880)
BAYONNE, N. J.

Manufacturers of A. C. and D. C. Motors and Generators. ½ to 1000 H.P.

MORSE SILENT CHAIN DRIVES



150 H. P. Morse Silent Chain driving ventilating fan.

Pay for themselves in service rendered

Morse Silent Chains are ideal for every drive or machine. They deliver continuously 98.6% of the power developed by the prime mover. They maintain this efficiency day after day, for many years, without let-up. Infact, Morse Drives pay for themselves many times over in the unfailing service they always give.

Let the Morse Engineer give you the benefit of his specialized experience in planning a drive for your particular conditions.

MORSE CHAIN COMPANY, ITHACA, N. Y.

There is a Morse Engineer near you

Atlanta, Ga. Baltimore, Md. Birmingham, Ala. Boston, Mass. Charlotte, N. C. Chicago, Ill. Cleveland, Ohio Denver, Colo. Detroit, Mich. Minneapolis, Minn. New York City Philadelphia, Pa. Pittsburgh, Pa. San Francisco, Cal. St. Louis, Mo. Toronto, Ont., Can. Winnipeg, Man., Can.

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CONTACT RESISTANCE ELECTROMAGNET

SUNDH
TRADE-MARK

	Bulletin
Alarm, High and Low Liquid Level	3610-3615
Automatic Fire Pump Panels, Combined Hand and (See Panels, Fire Pump).	
Automatic Starters (See Starters, Automatic).	
Automatic Transfer Switches	5600
Brakes, Magnetic	9920
Circuit Breakers	3800-3815
Contactors (See Switches, Magnet).	
Control, Machine Tool	9000
Controllers, Elevator	9999
Elevator Controllers	9999
Fire Pump Panels (See Panels, Fire Pump).	
Float Switches	3600-3625
Hand and Automatic Fire Pump Panels, Combined. (See Panels, Fire Pump).	
Hand Operated Switches	3600
Hand Starters (See Starters, Hand).	
High and Low Liquid Level Alarm Switches	3610-3615
Indicator, Level, Liquid, Remote	3625
Level, High and Low Liquid, Alarm Switch	3610-3615
Level, Indicator, Remote	3625
Lighting Panels, Remote Control	7100
Low Levels, High and, Alarm Switches	3610-3615
Machine Tool Control	9000
Magnetic Brakes (See Brakes, Magnetic).	
Magnet Operated Valves	5700
Magnet Switches, A. C.	7600
Magnet Switches, D. C.	7500
Magnets	6500
Manual Fire Pump Panels (See Panels, Fire Pump).	
Manual Starters (See Starters, Hand).	
Panels, Fire Pump	8800-8830
Panels, Lighting, Remote Control	7100
Panels, Pressure Regulator (See Pressure Regulator, also Panels, Special.)	
Panels, Special	5400-5423
Pressure Regulator, Gauge Type	4900-4902

	Bulletin
Pressure Regulator Panels (See Panels, Special).	
Regulator, Pressure (See Pressure Regulator).	
Regulators, Speed (See Speed Regulators).	
Relay, Tumbler	7250
Remote Controlled Lighting Panels	7100
Remote Controlled Speed Regulators (See Speed Regulators).	
Remote Liquid Level Indicator	3625
Remote Switches (See Switches, Remote, also Switches, Magnet).	
Self Starters (See Starters, Automatic).	
Solenoids (See Magnets).	
Solonoid Operated Valves	5700
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Speed Regulators	8500-8520
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Starters, Automatic	5300-5350
Starters, Hand	8320
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Sump Switches (See Switches, Float).	
Switches, Float	3600-3625
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Switches, Sump (See Switches, Float).	
Switches, Tank (See Switches Float).	
Switches, Time	6900
Switches, Transfer, Automatic	5600
Tank Switches (See Switches, Float).	
Terms	300
Time Switches	6900
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Valve Control	5700
Valve, Magnet Operated	5700
Valve, Remote Controlled	5700

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Penn. Central Power Co.
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Simplex Wires and Cables are rendering satisfactory service in many of the larger power stations of the country. Insulated with rubber, paper or varnished cambric and covered with braid, lead or steel armor, they are made for the particular conditions under which they are installed.

Why not submit your specifications to us?

CHICAGO
SAN FRANCISCO
NEW YORK

SIMPLEX WIRE & CABLE Co

MANUFACTURERS
201 DEVONSHIRE ST., BOSTON 9

FACTORY
AND MAIN OFFICE
AT BOSTON

Lapp Insulators do not fail!

LAPP INSULATOR CO., Inc.
LE ROY, N. Y.

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CHICAGO, Transelectric Co., Inc., 360 No. Michigan Ave.
CLEVELAND, O., Engineering Merchandising Synd cate, 608 Rockefeller Bldg.
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SAN FRANCISCO, S. Herbert Lanyon, 509 New Cal Bldg.
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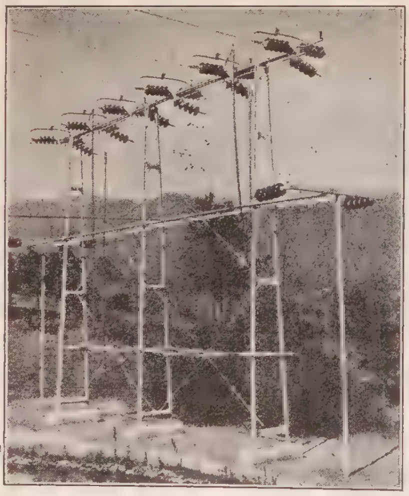


Simpler— Stronger— Better—

Installation K-P-F 60 KV. Switches, San Joaquin Lt. & Pwr. Corpn., Calif.

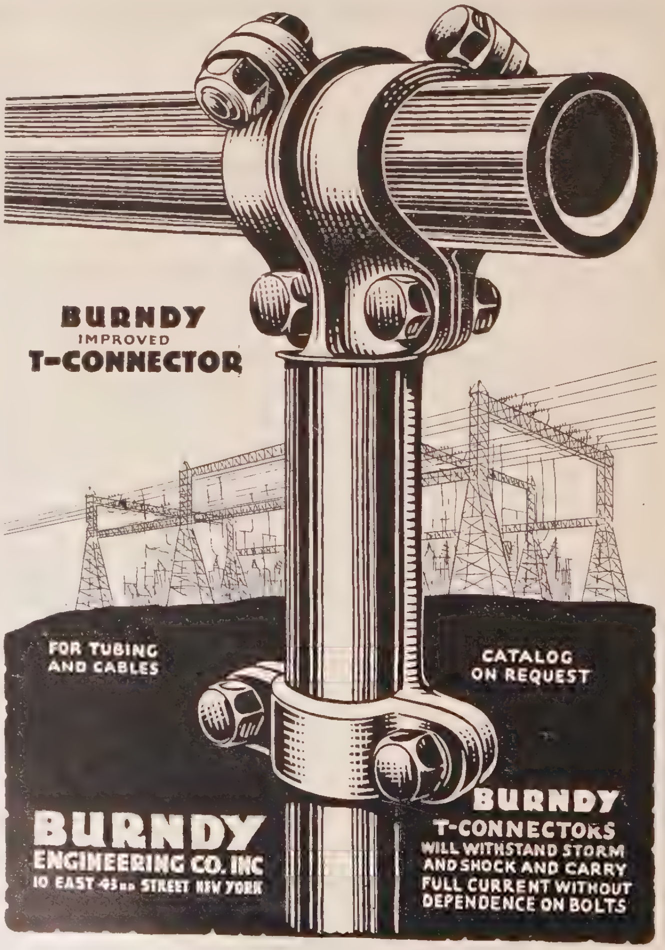
K-P-F POLE TOP SWITCHES consist of fewer parts, are more rugged and require less labor and material for installation than any other.

Each pole becomes a self-contained unit. Switches are shipped ready to bolt on to cross-arm in place of line insulator.

One crossarm supports it. Contacts are far removed from insulators and a unique device prevents sticking or freezing.

Send for bulletin K105 containing full details.

K-P-F ELECTRIC CO.
855-859 Howard St. **San Francisco**



PROFESSIONAL ENGINEERING DIRECTORY

For Consultants in the Fields of Engineering, and Related Arts and Sciences

PROFESSIONAL ENGINEERING DIRECTORY

For Consultants in the Fields of Engineering, and Related Arts and Sciences

Classified Advertiser's Index for Buyers

Manufacturers and agents for machinery and supplies used in the electrical and allied industries.

Note: For reference to the advertisements see the Alphabetical List of Advertisers on page 62.

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Allis-Chalmers Mfg. Co., Milwaukee
General Electric Co., Schenectady
Western Electric Co., All Principal Cities

AIR COMPRESSOR FILTERS
Midwest Air Filters, Inc., New York
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AMMETERS, VOLTMETERS
(See INSTRUMENTS, ELECTRICAL)

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Wagner Electric Corp., St. Louis
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New Departure Mfg. Co., The, Bristol, Conn.
Norma-Hoffmann Bearings Corp., Stamford, Conn.
Standard Steel & Bearings, Inc., Plainville, Conn.
Strom Ball Bearing Mfg. Co., Chicago

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Metropolitan Device Corp., Brooklyn, N. Y.
Western Electric Co., All Principal Cities
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Metropolitan Device Corp., Brooklyn, N. Y.
Standard Underground Cable Co., Pittsburgh

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National Carbon Co., Inc., Cleveland
Westinghouse Elec. & Mfg. Co., E. Pittsburgh
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General Electric Co., Schenectady
Minerallac Electric Co., Chicago
Standard Underground Cable Co., Pittsburgh
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CABLES
(See WIRES AND CABLES)

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Belden Mfg. Co., Chicago
Irvington Varnish & Ins. Co., Irvington, N. J.

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Morse Chain Co., Ithaca, N. Y.

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Cutter Co., The, Philadelphia
Roller-Smith Co., New York
Sundh Electric Co., Newark, N. J.
Western Electric Co., All Principal Cities
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Condit Electrical Mfg. Co., S. Boston
General Electric Co., Schenectady
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Belden Mfg. Co., Chicago
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CONDENSERS *Steam*
Allis-Chalmers Mfg. Co., Milwaukee
General Electric Co., Schenectady
Westinghouse Elec. & Mfg. Co., E. Pittsburgh
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General Radio Co., Cambridge, Mass.

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General Electric Co., Schenectady

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Rowan Controller Co., Baltimore
Sundh Electric Co., Newark, N. J.
Western Electric Co., All Principal Cities
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Northwestern Electric Co., Chicago
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COPPER CLAD WIRE
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DYNAMOS
(See GENERATORS AND MOTORS)

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Sturtevant Company, B. F., Boston
Oil
Allis-Chalmers Mfg. Co., Milwaukee
Sturtevant Company, B. F., Boston
Steam
Allis-Chalmers Mfg. Co., Milwaukee
Sturtevant Company, B. F., Boston

FANS, MOTOR
Century Electric Co., St. Louis
General Electric Co., Schenectady
Star Electric Motor Co., Newark, N. J.
Sturtevant Company, B. F., Boston
Wagner Electric Corp., St. Louis
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

FARM LIGHTING GENERATORS
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

FIBRE
Belden Mfg. Co., Chicago
National Vulcanized Fibre Co., Wilmington, Del.

FLOW METERS
Cory & Son, Inc., Chas., New York
General Electric Co., Schenectady
Spray Engineering Co. Boston

FURNANCES, ELECTRIC
General Electric Co., Schenectady
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

FUSES *Enclosed Refillable*
General Electric Co., Schenectady
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh
Enclosed Non-Refillable
General Electric Co., Schenectady
Western Electric Co., All Principal Cities
Open Link
General Electric Co., Schenectady
Metropolitan Device Corp., Brooklyn, N. Y.
Western Electric Co., All Principal Cities
High Tension
Metropolitan Device Corp., Brooklyn, N. Y.
Western Electric Co., All Principal Cities

GEARS, FIBRE
General Electric Co., Schenectady
National Vulcanized Fibre Co., Wilmington, Del.

GENERATORS AND MOTORS
Allis-Chalmers Mfg. Co., Milwaukee
Burke Electric Co., Erie, Pa.
Century Electric Co., St. Louis
Chandeysson Electric Co., St. Louis
Electric Specialty Co., Stamford, Conn.
Electro-Dynamic Co., Bayonne, N. J.
General Electric Co., Schenectady
Northwestern Electric Co., Chicago
Star Electric Motor Co., Newark, N. J.
Sturtevant Company, B. F., Boston
Wagner Electric Corp., St. Louis
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

GENERATING STATION EQUIPMENT
Allis-Chalmers Mfg. Co., Milwaukee
Burke Electric Co., Erie, Pa.
General Electric Co., Schenectady
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

GROUND RODS
Copperweld Steel Co., Rankin, Pa.
Western Electric Co., All Principal Cities

HEADLIGHTS
Ohio Brass Co., Mansfield, O.

HEATERS, INDUSTRIAL
General Electric Co., Schenectady
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

IGNITION SYSTEMS, AUTOMOBILE
Wagner Electric Corp., St. Louis

INDICATORS, LOAD
Cory & Son, Inc., Chas., New York

INDICATORS, SPEED
Biddle, James G., Philadelphia
Roller-Smith Co., New York

INDICATORS, WATER LEVEL
Cory & Son, Inc., Chas., New York

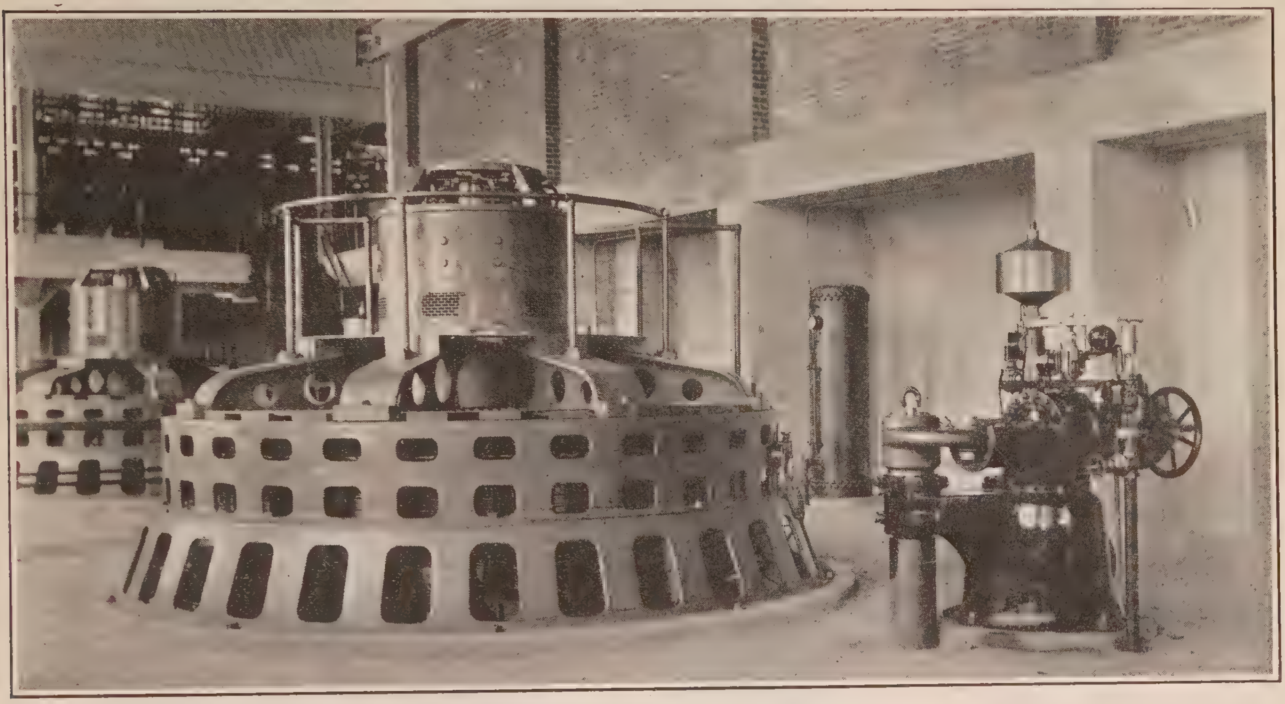
INSTRUMENTS, ELECTRICAL
Graphic
Biddle, James G., Philadelphia
Bristol Co., The, Waterbury, Conn.
Ferranti, Ltd., London Eng.
Ferranti Meter & Transformer Mfg. Co., Ltd., Toronto, Ont.
General Electric Co., Schenectady
Westinghouse Elec. & Mfg. Co., E. Pittsburgh
Indicating
Ferranti, Ltd., London, Eng.
Ferranti Meter & Transformer Mfg. Co., Ltd., Toronto, Ont.
General Electric Co., Schenectady
Jewell Elec. Instrument Co., Chicago
Roller-Smith Co., New York
Westinghouse Elec. & Mfg. Co., E. Pittsburgh
Weston Elec. Inst. Corp., Newark, N. J.
Integrating
Biddle, James G., Philadelphia
Duncan Elec. Mfg. Co., Lafayette, Ind.
Ferranti, Ltd., London, Eng.
Ferranti Meter & Transformer Mfg. Co., Ltd., Toronto, Ont.
General Electric Co., Schenectady
Roller-Smith Co., New York
Sangamo Elec. Co., Springfield, Ill.
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh
Radio
General Radio Co., Cambridge, Mass.
Jewell Elec. Instrument Co, Chicago
Repairing and Testing
Electrical Testing Laboratories, New York
Jewell Elec. Instrument Co., Chicago

I. P. Morris Hydraulic Turbines

The Wm. Cramp & Sons Ship & Engine Building Co.

Richmond and Norris Sts., Philadelphia

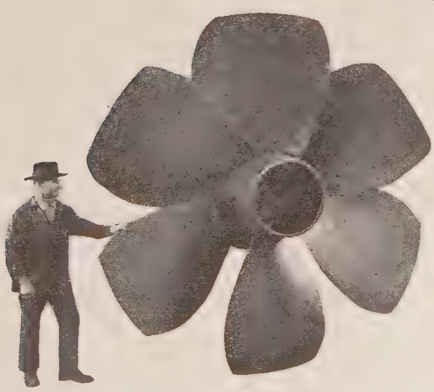
New York Office: 100 Broadway — **Birmingham Office: American Trust Building**



Five 1500 Horsepower Turbines Equipped with Moody High Speed Runners are installed in this plant at Anson, Maine, for the **Great Northern Paper Company.**

Head 20 Feet — **Speed 150 R. P. M.**

Official test of these units conducted by Prof. Charles M. Allen showed a turbine efficiency of 90.9 per cent.



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Designers and builders of the Johnson Hydraulic Valve and the Moody Spiral Pump

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General Electric Co., Schenectady
Jewell Elec. Instrument Co., Chicago
Metropolitan Device Corp., Brooklyn, N. Y.
Roller-Smith Co., New York
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh
Weston Elec. Inst. Corp., Newark, N. J.
Telegraph
Western Electric Co., All Principal Cities

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Cloth
Irvington Varnish & Ins. Co., Irvington, N. J.
Minerallac Electric Co., Chicago
Westinghouse Elec. & Mfg. Co., E. Pittsburgh
Composition
American Lava Corp., Chattanooga
Bakelite Corporation, New York
Belden Mfg. Co., Chicago
Westinghouse Elec. & Mfg. Co., E. Pittsburgh
Compounds
Minerallac Electric Co., Chicago
Standard Underground Cable Co., Pittsburgh
Sherwin-Williams Co., Cleveland
Western Electric Co., All Principal Cities
Fibre
National Vulcanized Fibre Co., Wilmington, Del.
West Va. Pulp & Paper Co., New York
Lava
American Lava Corp., Chattanooga, Tenn.
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New England Mica Co., Waltham, Mass.
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Silk
Irvington Varnish & Ins. Co., Irvington, N. J.
Tape
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Minerallac Electric Co., Chicago
Okonite Co., The, Passaic, N. J.
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh
Varnishes
General Electric Co., Schenectady
Irvington Varnish & Ins Co., Irvington, N. J.
Minerallac Electric Co., Chicago
Sherwin-Williams Co., Cleveland

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METERS, ELECTRICAL
(See INSTRUMENTS, ELECTRICAL)

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Bakelite Corporation, New York
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Burke Electric Co., Erie, Pa.
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

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Fansteel Products Co., Inc., North Chicago

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(See GENERATORS AND MOTORS)

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Roller-Smith Co., New York
Weston Elec. Instr. Corp., Newark ,N. J.

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Sharples Specialty Co., The, Philadelphia
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

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(See SWITCHBOARDS)

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(See PROFESSIONAL ENGINEERING DIRECTORY)

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Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

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Western Electric Co., All Principal Cities

POLES—TIES, WOOD
Western Electric Co., All Principal Cities

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Electrical Dev. & Mach. Co., Philadelphia
Standard Underground Cable Co., Pittsburgh
Western Electric Co., All Principal Cities

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Western Electric Co., All Principal Cities

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Matthews Corp., W. N., St. Louis

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Rockwood Mfg. Co., The, Indianapolis

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Allis-Chalmers Mfg. Co., Milwaukee
Goulds Mfg. Co., Seneca Falls, N. Y.

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Westinghouse Elec. & Mfg. Co., E. Pittsburgh

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General Electric Co., Schenectady
Wagner Electric Corp., St. Louis
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

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Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

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Westinghouse Elec. & Mfg. Co., E. Pittsburgh

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Sundh Electric Co., Newark, N. J.
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

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Westinghouse Elec & Mfg. Co., E. Pittsburgh

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Westinghouse Elec. & Mfg. Co., E. Pittsburgh

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Westinghouse Elec. & Mfg. Co., E. Pittsburgh

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Sundh Electric Co., Newark, N. J.
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

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Westinghouse Elec. & Mfg. Co. E. Pittsburgh

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General Electric Co., Schenectady
Metropolitan Device Corp., Brooklyn, N. Y.
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Westinghouse Elec. & Mfg. Co., E. Pittsburgh

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Minerallac Electric Co., Chicago
Sundh Electric Co., Newark, N. J.
Westinghouse Elec. & Mfg. Co., E. Pittsburgh
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Electrical Dev. & Mach. Co., Philadelphia
General Electric Co., Schenectady
K-P-F Electric Co., San Francisco
Matthews Corp., W. N., St. Louis
Pacific Electric Mfg. Co., San Francisco
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General Electric Co., Schenectady
Matthews Corp., W. N., St. Louis
Metropolitan Device Corp., Brooklyn, N. Y.
Thoner & Martens, Boston
Knife
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General Electric Co., Schenectady
Matthews Corp., W. N., St. Louis
Western Electric Co., All Principal Cities
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Condit Electrical Mfg. Co., So. Boston
General Electric Co., Schenectady
Pacific Electric Mfg. Co., San Francisco
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh
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General Electric Co., Schenectady
Rowan Controller Co. Baltimore
Sundh Electric Co., Newark, N. J.
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E Pittsburgh

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Biddle, James G., Philadelphia

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Fansteel Products Co., Inc., North Chicago

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Cory & Son, Inc., Chas., New York
Western Electric Co., All Principal Cities

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Electrical Testing Labs., New York

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For Testing, Compression, Ductility, Endurance, etc.
Olsen Testing Machine Co., Tinius, Philadelphia

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Pacific Coast Steel Co., San Francisco
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Ferranti, Ltd., London, Eng.
Ferranti Meter & Transformer Mfg. Co., Ltd., Toronto, Ont.
General Electric Co., Schenectady
Kuhlman Electric Co., Bay City, Mich.
Moloney Electric Co., St. Louis
Pittsburgh Transformer Co., Pittsburgh
Wagner Electric Corp., St. Louis
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh
Factory
American Transformer Co., Newark, N. J.
Kuhlman Electric Co., Bay City, Mich.
Moloney Electric Co., St. Louis
Pittsburgh Transformer Co., Pittsburgh
Wagner Electric Corp., St. Louis
Western Electric Co., All Principal Cities
Furnace
Allis-Chalmers Mfg. Co., Milwaukee
American Transformer Co., Newark, N. J.
Moloney Electric Co., St. Louis
Pittsburgh Transformer Co., Pittsburgh
Metering
American Transformer Co., Newark, N. J.
Ferranti, Ltd., London, Eng.
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33 West 39th Street, New York

Classified Advertiser's Index for Buyers—*Continued*

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Radio
- American Transformer Co., Newark, N. J.

Street Lighting
- Kuhlman Electric Co., Bay City, Mich.
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TROLLEY LINE MATERIALS
- General Electric Co., Schenectady
- Ohio Brass Co., Mansfield, O.
- Western Electric Co., All Principal Cities
- Westinghouse Elec. & Mfg. Co., E. Pittsburgh

TURBINES, HYDRAULIC
- Allis-Chalmers Mfg. Co., Milwaukee
- Cramp & Sons Ship & Engine Bldg. Co., The Wm., Philadelphia

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- General Electric Co., Schenectady
- Sturtevant Company, B. F., Boston
- Western Electric Co., All Principal Cities
- Westinghouse Elec. & Mfg. Co., E. Pittsburgh

TURBINE SIGNAL SYSTEMS
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TURBO-GENERATORS
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- Westinghouse Elec. & Mfg. Co., E. Pittsburgh

VALVE CONTROL, ELECTRIC
- Cory & Son, Inc., Chas., New York
- Liberty Electric Corp., Stamford, Conn.

VALVES, JOHNSON HYDRAULIC
- Cramp & Sons Ship & Engine Bldg. Co., The Wm., Philadelphia

VARNISHES, INSULATING
- General Electric Co., Schenectady
- Irvington Varnish & Ins. Co., Irvington, N. J.
- Minerallac Electric Co., Chicago
- Sherwin-Williams Co., Cleveland
- Westinghouse Elec. & Mfg. Co., E. Pittsburgh

WELDING EQUIPMENT, ELECTRICAL
- General Electric Co., Schenectady
- Ohio Brass Co., Mansfield, O.
- Westinghouse Elec. & Mfg. Co., E. Pittsburgh

WIRES AND CABLES

Armored Cable
- Atlantic Ins. Wire & Cable Co., Rome, N. Y.
- Belden Mfg. Co., Chicago
- Boston Ins. Wire & Cable Co., Boston
- General Electric Co., Schenectady
- Hazard Manufacturing Co., Wilkes-Barre, Pa.
- Kerite Ins. Wire & Cable Co., New York
- Okonite Company, The, Passaic, N. J.
- Roebling's Sons Co., John A., Trenton, N. J.
- Simplex Wire & Cable Co., Boston
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- Western Electric Co., All Principal Cities

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- Belden Mfg. Co., Chicago
- General Electric Co., Schenectady

Automotive
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- Belden Mfg. Co., Chicago
- Boston Ins. Wire & Cable Co., Boston
- General Electric Co., Schenectady
- Kerite Ins. Wire & Cable Co., New York
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- Simplex Wire & Cable Co., Boston
- Standard Underground Cable Co., Pittsburgh
- Western Electric Co., All Principal Cities

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- Hazard Manufacturing Co., Wilkes-Barre, Pa.
- Roebling's Sons Co., John A., Trenton, N. J.
- Standard Underground Cable Co., Pittsburgh
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- Boston Ins Wire & Cable Co., Boston
- General Electric Co., Schenectady
- Hazard Manufacturing Co., Wilkes-Barre, Pa.
- Okonite Company, The, Passaic, N. J.
- Roebling's Sons Co., John A., Trenton, N. J.
- Simplex Wire & Cable Co., Boston
- Standard Underground Cable Co., Pittsburgh
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- Western Electric Co., All Principal Cities

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- Hazard Manufacturing Co., Wilkes-Barre, Pa.
- Kerite Ins. Wire & Cable Co., New York
- Okonite Company, The, Passaic, N. J.
- Roebling's Sons Co., John A., Trenton, N. J.
- Simplex Wire & Cable Co., Boston
- Standard Underground Cable Co., Pittsburgh
- Western Electric Co., All Principal Cities

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- Belden Mfg. Co., Chicago
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- Roebling's Sons Co., John A., Trenton, N. J.
- Standard Underground Cable Co., Pittsburgh
- Western Electric Co., All Principal Cities

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- Belden Mfg. Co., Chicago
- Boston Ins. Wire & Cable Co., Boston
- General Electric Co., Schenectady
- Hazard Manufacturing Co., Wilkes-Barre, Pa.
- Kerite Ins. Wire & Cable Co., New York
- Okonite Company, The, Passaic, N. J.
- Roebling's Sons Co., John A., Trenton, N. J.
- Simplex Wire & Cable Co., Boston
- Standard Underground Cable Co., Pittsburgh
- Western Electric Co., All Principal Cities

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- Roebling's Sons Co., John A., Trenton, N. J.
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- General Electric Co., Schenectady
- Kerite Ins. Wire & Cable Co., New York
- Okonite Company, The, Passaic, N. J.
- Roebling's Sons Co., John A., Trenton, N. J.
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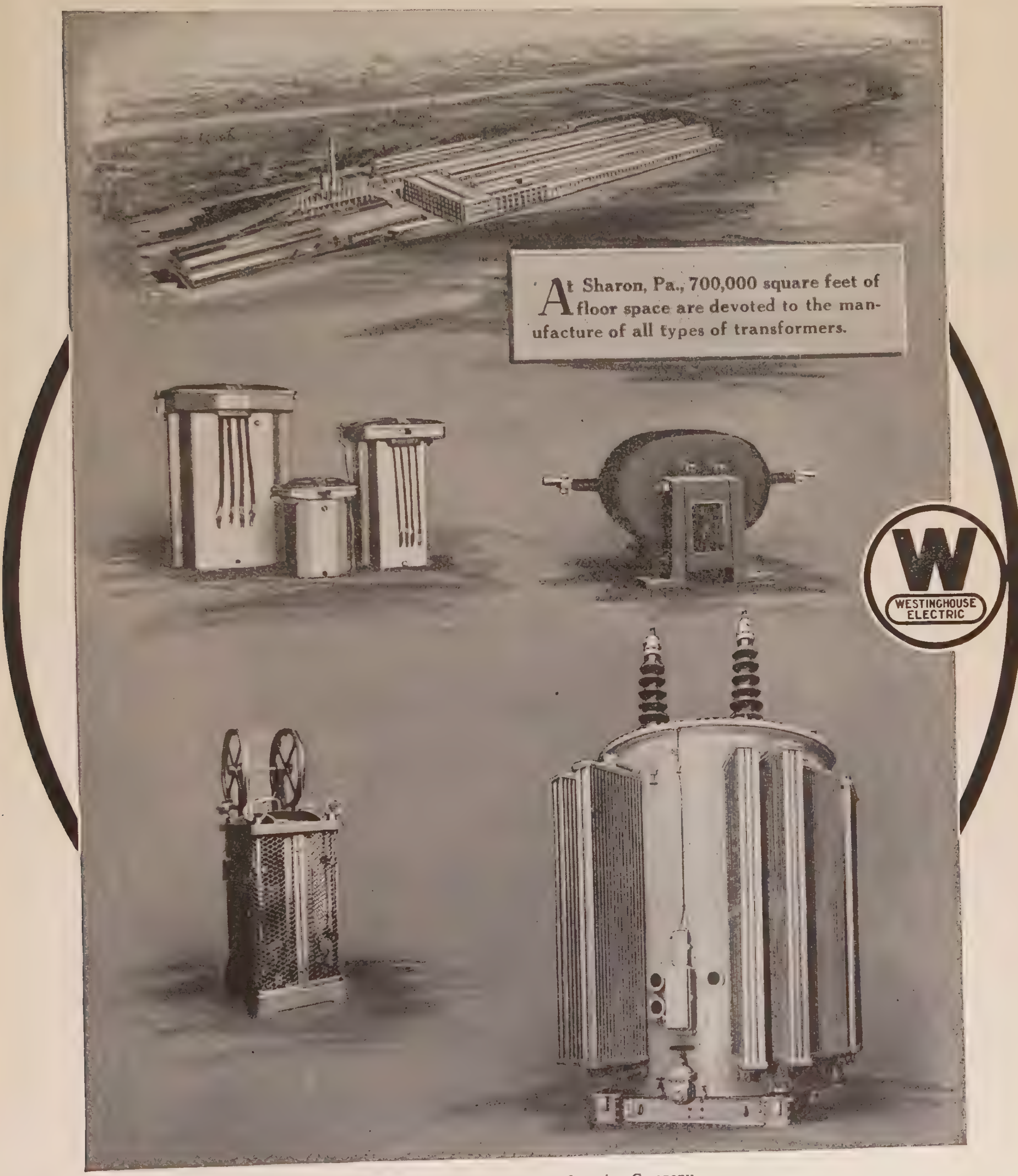
The New Westinghouse Transformer Works



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Westinghouse

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